COMMON RAVENS IN ALASKA'S NORTH SLOPE OIL FIELDS:

AN INTEGRATED STUDY USING LOCAL KNOWLEDGE AND SCIENCE

By

Stacia Ann Backensto

RECOMMENDED:

Advisory Committee Co-Chair

Advisory Committee Co-Chair

Chair, Department of Biology and Wildlife

APPROVED:

Dean, College of Natural Science and Mathematics

Dean of the Graduate School

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Stacia Ann Backensto, B.S.

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ABSTRACT

Common ravens (*Corvus corax*) that nest on human structures in the Kuparuk and Prudhoe Bay oil fields on Alaska's North Slope are believed to present a predation risk to tundra-nesting birds in this area. In order to gain more information about the history of the resident raven population and their use of anthropogenic resources in the oil fields, I documented oil field worker knowledge of ravens in this area. In order to understand how anthropogenic subsidies in the oil fields affect the breeding population, I examined the influence of types of structures and food subsidies on raven nest site use and productivity in the oil fields. Oil field workers provided new and supplemental information about the breeding population. This work in conjunction with a scientific study of the breeding population suggests that structures in the oil fields were important to ravens throughout the year by providing nest sites and warm locations to roost during the winter. The breeding population was very successful and appears to be limited by suitable nest sites. The landfill is an important food source to ravens during winter, and pick-up trucks provide a supplemental source of food throughout the year. Further research will be necessary to identify how food (anthropogenic and natural) availability affects productivity and the degree to which ravens impact tundra-nesting birds.

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I thank all the oil field workers that participated in the local knowledge study; they were very generous with their time after working 12-18 hours shifts. I also thank the oil field workers who assisted with catching ravens and encouraged me to "think like a raven". I am extremely grateful for the field assistance provided by K. Barnes, M. Cunningham, E. Lester, T. Thomas, F. Merrill, R. Darvill, J. Klima, J. Cunningham, and M. Miller, and G. Penner.

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CHAPTER 1: INTRODUCTION

Common raven (*Corvus corax*) populations have increased throughout many portions of their range, especially near human settlements (Dare, 1986; Ratcliffe, 1997; Boarman and Heinrich, 1999; Leibezeit and George, 2002; Preston, 2005; Sim et al., 2005, Boarman et al., 2006), and have been implicated in the decline of several species, many of which are endangered (Avery et al., 1995; Leibezeit and George, 2002; Boarman, 2003; Kelly et al., 2005; Hebert and Golightly, 2007; USFWS, 2008). Ravens have recently become a wildlife management concern on Alaska's North Slope. Concern about their potential impact as predators of tundra-nesting waterfowl and shorebirds has increased in areas where anthropogenic food and structures exist (Day, 1998), especially for species of conservation concern such as yellow-billed loons (*Gavia adamsii*) and Steller's (*Polysticta stelleri*) and spectacled eiders (*Somateria fisheri*; Sea Duck Joint Venture Continental Technical Team, 2003; Earnst, 2004). Federal and local wildlife biologists who participated in a USFWS-sponsored workshop about nest predators (USFWS, 2003 *public communications*) expressed a need for baseline information about the raven population on the North Slope. Specifically, they recommended research focused on monitoring abundance and distribution of ravens in developed and undeveloped areas, and documenting the effect of ravens on tundra-nesting birds (USFWS, 2003). Their recommendations and concerns motivated this study of ravens in the Kuparuk and Prudhoe Bay oil fields (Appendix 1.1).

It appears raven populations have increased on the North Slope, where oil and gas development has occurred over the last 40 years (Appendix 1.2; National Research Council, 2003; National Audubon Society, 2009). Biologists have known that ravens nested in the oil fields since 1986, but it is unclear when they first began nesting (B. Anderson, ABR Inc. pers. comm.). The construction and establishment of structures in the Prudhoe Bay oil fields, beginning in 1968, introduced suitable nest sites for ravens, places to perch, and provided a large anthropogenic food subsidy (e.g., landfill) that were largely unavailable prior to development. Development expanded to the west of Prudhoe Bay by 1978, with the establishment of the Kuparuk oil fields (Appendix 1.3.). Roughly half of the structures that currently exist in the Kuparuk and Prudhoe Bay oil fields were built by 1983 (Appendix D, National Research Council, 2003). Currently ~800,000 ha of the North Slope are leased for oil and gas activities (Alaska Department of Natural Resources, 2009). The infrastructure footprint (gravel pads, roads, airstrips, and exploration sites) of both oil fields, including smaller satellite oil fields to the east and west and nearby offshore islands to the north, is roughly 3670 ha (National Research Council, 2003). Ravens also nest on other structures elsewhere on the North Slope, such as the U.S. Air Force Alaska Radar System (ARS) towers that were established in 1957 in Barrow and Pt. Lay (Appendix 1.4; Day, 1998; Lackenbauer et al., 2005).

Using methods from social and natural sciences, I investigated aspects of raven ecology in the oil fields using two information sources: local knowledge of ravens held by oil field workers and a scientific study of ravens breeding in the oil fields. The paradigm in science that social and ecological systems are separate enterprises of knowledge production is changing (Gunderson and Holling, 2002; Alberti et al., 2003; Nabhan, 2003; Miller et al., 2008; Berkes and Berkes, 2009), with many arguing that the framing of ecological and social systems as interacting or coupled "social-ecological systems" improves our understanding of issues pertaining to the vulnerability and resilience of society (Chapin et al., 2006). Additionally, understanding the influence of human values on ecological processes has been argued as a major scientific challenge confronting urban avian ecologists (Bowman and Marzluff, 2001). Local knowledge (also referred to as indigenous knowledge and traditional knowledge) has been recognized as another source of information about ecological phenomena that can benefit scientific studies and improve our understanding of social-ecological processes (Berkes et al., 2000; Pierotti and Wildcat, 2000; Krupnik and Jolly, 2002; ACIA, 2004; AHDR, 2004; Huntington et al., 2004; Drew and Henne, 2006; Ommer and Coasts Under Stress Research Project Team, 2007).

Knowledge held by local people may be especially relevant to raven ecology because ravens have associated with people throughout human history. Ravens have a place in the stories, art, and place names of many cultures, appearing as creators of the universe, companions to hunters, tricksters, revered spiritual entities, symbols of wilderness, auguries, and for some, harbingers of death and doom (Conner et al., 1976; Nelson, 1983; Smelcer, 1991; Heinrich, 1999; Moore, 2002; Mortensen, 2003; Marzluff and Angell, 2005). The associations and cultural relationships humans have with ravens suggest that residents of a particular place can provide observations and detailed information about ravens, and by acquiring this knowledge it may be possible to gain a more in-depth understanding of the ways ravens adapt to and exploit human activities and settlements. In the first part of this thesis I focus on knowledge of ravens held by oil field workers. These are people whose livelihoods and lifestyles do not directly depend on an in-depth understanding of local ecology, but who may still acquire ecological knowledge for other reasons. In this sense local knowledge is not race or ethnically linked but is derived from long-term experiences with place (Nygren, 1999; Usher, 2000; Nabhan, 2003; Corburn, 2005; Loring and Gerlach, in press). For logistical reasons I restricted my study of local knowledge to oil field workers; however, I recognize that Alaska Natives from the nearby village of Nuiqsut and several wildlife biologists who have conducted many years of research in the oil fields likely hold local knowledge of ravens as well.

The central reason for documenting oil field workers' knowledge of ravens was to acquire additional historical and contemporary information about the raven population in the oil fields in order to fill knowledge gaps and supplement the biological study of the breeding population. My general overarching questions were:

1) To what extent has raven abundance changed in the oil fields over time?

2) Where did ravens nest in the oil fields prior to my study?

3) What aspects of the oil fields subsidize the resident raven population and does raven use of subsidies vary seasonally?

In Chapter 2, based on interviews and questionnaires completed by workers, I described raven population change, seasonal use of oil field infrastructure and anthropogenic food sources, and predatory behavior. Additionally, I sought to gain insight into workers' association with ravens and to characterize the human dimension of raven ecology and management in the oil fields; therefore I also documented and described oil field workers' personal perspectives of ravens. Understanding the context of local knowledge is fundamental to working with and interpreting this type of information (Usher, 2000; Agrawal, 2002; Kofinas et al., 2002; Huntington et al., 2006). Thus, I also described workers' observations relative to their opportunities to observe ravens in the oil fields.

In the second part of this thesis I focused on nesting ecology of ravens in the oil fields based on my four-year study. Various demographic and environmental factors affect bird populations; breeding density for species with special nest site requirements is typically limited by nest site availability (Newton, 1998). In raven populations, social behavior, availability of food, water, and nest sites, and human persecution are factors known to affect breeding densities (Skarphedinsson et al., 1990; Knight and Kawashima, 1993; Steenhof et al. 1993; Dunk et al., 1997; Ratcliffe, 1997; Sara and Busalacchi, 2003; Tryjanowski et al., 2004). Ravens with access to anthropogenic food and nest sites often have higher breeding densities and productivity (Marzluff and Neatherlin, 2006; White, 2006; Kristan and Boarman, 2007). However, little is known about factors limiting the size and reproductive success of ravens breeding in the North Slope oil fields. Chapter 2 addresses how anthropogenic factors influence raven nest site use and productivity in the oil fields. I evaluated raven nest site use and productivity relative to these subsidies to better understand the importance of anthropogenic food and oil field structures. In addition, some hypotheses in this investigation were shaped by worker's observations of nest site use and winter activities of ravens.

I conclude this thesis by synthesizing the results of Chapters 1 and 2 with additional data I collected during the breeding study about the foraging ecology and movements of breeding ravens. In doing so, I illustrate the ways oil field workers' knowledge of ravens benefited my study of breeding ravens. Finally, I present a set of management recommendations for the raven population in the oil fields.

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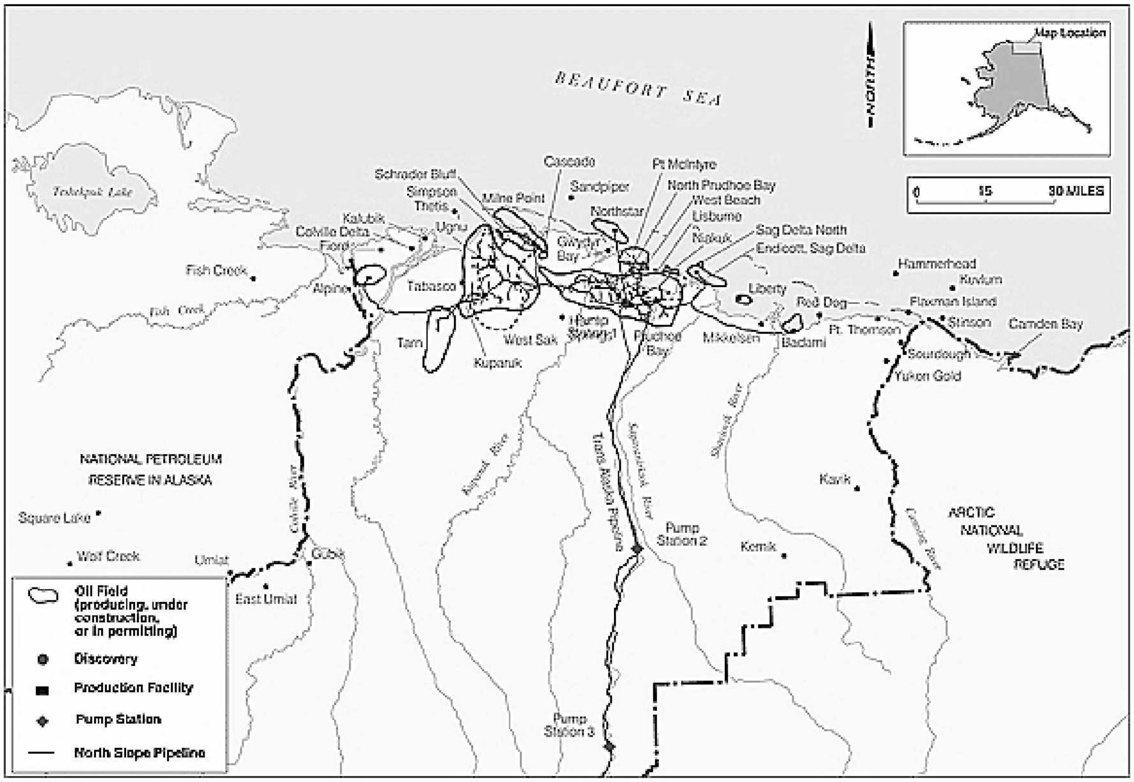
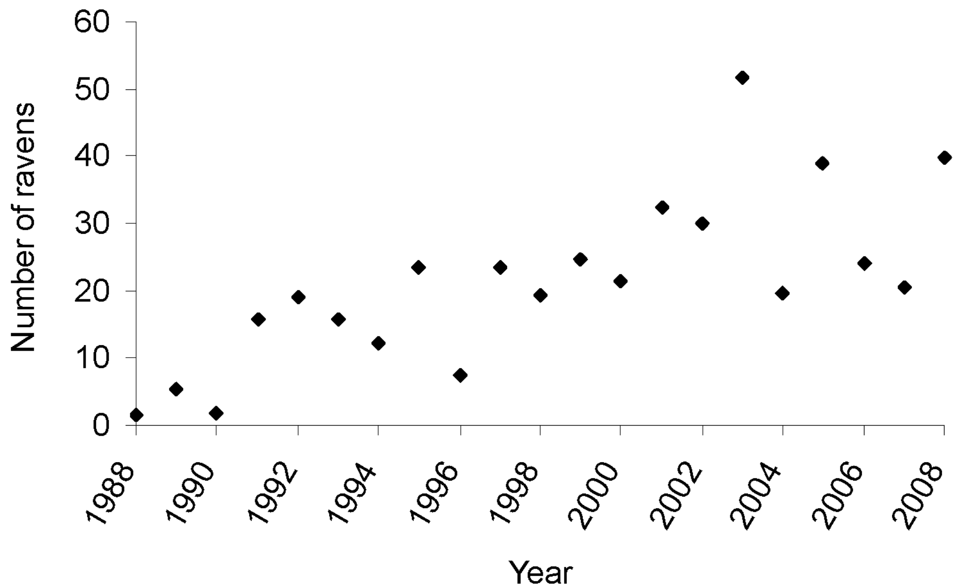
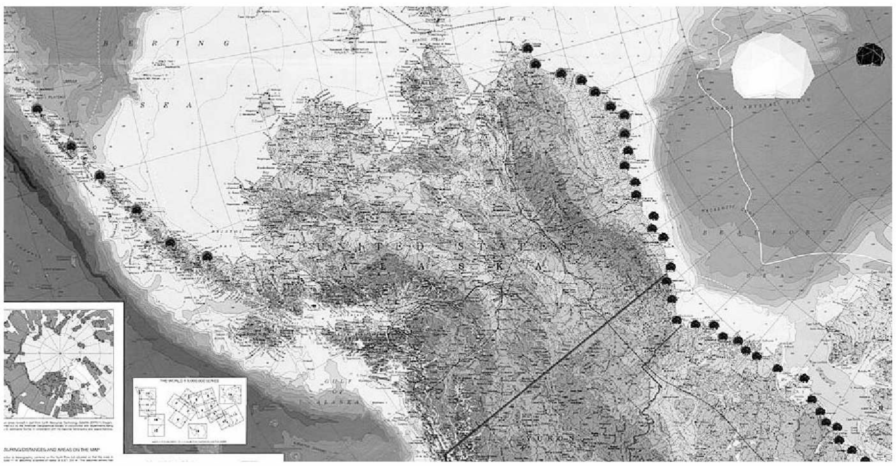
Appendix 1.1. Location of Alaska's North Slope oil fields (Source: Trans-Alaska Pipeline System Renewal EIS, http://tapseis.anl.gov).



Appendix 1.2. Christmas Bird Counts of ravens at Prudhoe Bay, Alaska from 1988-2008 (National Audubon Society, 2009). Counts are standardized by number of birds counted per party hour to reflect effort expended searching for ravens.



Appendix 1.5. U.S. Air Force Alaska Radar System (ARS) towers in Alaska. Dots represent locations of ARS towers, also known as the Distant Early Warning System (DEW) Line (Source: S. Fritz, Department of Anthropology, UAF).



CHAPTER 2. AN ALTERNATIVE INFORMATION SOURCE ON COMMON RAVENS (*CORVUS CORAX*) OF ALASKA'S NORTH SLOPE OIL FIELDS: LOCAL ECOLOGICAL KNOWLEDGE OF OIL FIELD WORKERS.[1]

ABSTRACT

Local ecological knowledge collected from well-informed individuals in any community, whether indigenous or non-indigenous, potentially benefits ecological studies by filling knowledge gaps, providing new insights, confirming scientific observations, and helping scientists develop new hypotheses to test. To gain additional information for an ecological study on raven use of anthropogenic resources in Alaska's North Slope oil fields, I documented oil field worker knowledge through formal interviews and standardized survey instruments, such as questionnaires. Through this combination of methods and techniques, I gained a historical perspective about raven use of structures for nesting over the course of more than 40 years of oil field production. Workers observed that ravens have nested in the oil fields since 1971, often on processing facilities. This information, combined with perspectives about raven responses to human activities and use of heat sources, aided in hypothesis development and interpretation of results from an analysis of nest site use. Raven use of the Prudhoe Bay landfill and roosting behavior (groups of 20-50 ravens) at a nearby (<5 km) processing facility during winter matched observations of other raven populations at landfills. Observations made by ~80% of workers of ravens using pick-

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[1] Prepared for submission to *Arctic* as Backensto, S. and G. Kofinas An Alternative Information Source on Common Ravens (*Corvus corax*) of Alaska's North Slope Oil Fields: Local Ecological Knowledge of Oil Field Workers.

up trucks and dumpsters supplemented my own observations and suggest that these resources, despite official waste policies, provide access to anthropogenic food. Personal perspectives about ravens of the North Slope that are grounded in depth experience, cultural, and management contexts should be considered in future research and management planning. Future research efforts should consider the potential contributions of workers' experiences such as type of work, location of work, and longevity in the oil fields to collect specific information about ravens.

INTRODUCTION

The social-ecological environment of the Arctic is changing rapidly as a result of climate change and activity in extracting natural resources (ACIA, 2004; AHDR, 2004). Local knowledge can assist science in studying these changes by: 1) gauging confidence in individual conclusions, 2) identifying new ideas for further investigations, 3) comparing information gathered at different scales, and 4) examining potential mechanisms to explain local and scientific observations (Huntington et al., 2004a). In northern Alaska, there has been considerable effort to document indigenous knowledge (Krupnik and Jolly, 2002; Huntington et al., 2004a; Kofinas et al., 2002; Fernandez-Gimenez et al., 2006; Gearheard et al., 2006; Rattenbury et al., 2009), however, little to no work has been done to document the knowledge of oil field workers, who collectively make up one of the largest communities on the North Slope of Alaska. Two major documents, *Cumulative Impacts Assessment of Oil and Gas Activities on the North Slope* (National Research Council, 2003) and *Natural History of an Arctic Oil Field* (Truett and Johnson, 2000) address the relationship between oil and gas development and change in biotic and human communities on the North Slope, yet neither provides any substantial detail about oil field workers or the ecological changes they have witnessed over time. The only published account of an oil field worker's observations I was able to locate was Pamperin et al. (2006), which showed that one worker's observation of arctic (*Vulpes lagopus*) and red fox (*V. vulpes*) interactions confirmed scientists' suspicions that red fox preyed upon arctic fox.

Earlier perspectives of oil field workers may have contributed to a lack of research interest in North Slope oil field workers as a source of information about ecological change in Alaska's arctic. For example, Lopez (1986:357) characterized Alaska's North Slope oil field workers as having "the mentality [that] is largely innocent of history and arctic ecology", and "[perceiving] that the Arctic was really a great wasteland 'with a few stupid birds.'" Counter to that statement, research into the oil field worker profession shows that the culture and image of today's oil field workers in North America has changed from the widely held "manly man's or macho" profession to a safety-conscious, professional image (Ely and Meyerson, 2008).

Oil field workers on Alaska's North Slope may be an important source of information about wildlife populations that inhabit this area because of their year-round presence and widespread activities on this landscape. Local knowledge elsewhere in the Arctic has informed scientific studies of beluga whales (*Delphinapterus leucus*) and arctic birds (Gilchrist and Robertson, 2000; Mallory et al., 2003; Huntington et al., 2004b; Gilchrist et al., 2005). Workers' knowledge about wildlife in the oil fields may benefit existing and future research about species that are subsidized by this environment and are predators of tundra-nesting birds, such as common ravens (*Corvus corax*), glaucous gulls (*Larus hyperboreus*), arctic fox, and grizzly bears (*Ursus arctos*) (Day, 1998; USFWS, 2003). This study focused on the population of ravens in the oil fields.

Ravens nest on structures throughout the Kuparuk and Prudhoe Bay oil fields. The North Slope population has become a concern for tundra-nesting birds, especially for those species with special conservation status, because ravens are known nest predators throughout their range (Day, 1998; Boarman and Heinrich 1999; USFWS, 2003). In 2004, I initiated a study to learn more about the breeding and foraging ecology of ravens in the oil fields in order to understand their impact as predators on tundra-nesting birds and the extent to which infrastructure and anthropogenic foods benefit the population. I considered oil field workers as a source of additional information for my ecological study.

This Study

I documented oil field worker knowledge about ravens in the Kuparuk and Prudhoe Bay oil fields of Alaska for three main reasons. There was little historical information about this raven population, mostly limited to an annual index of the winter population's size at the landfill in Prudhoe Bay (Christmas Bird Count; National Audubon Society, 2009; Appendix 2.1) and anecdotal observations of raven nests and summer foraging behaviors collected opportunistically from 1986 - 2002 by a local environmental consulting firm (B. Anderson, ABR Inc., pers. comm.). One primary objective of this study, therefore, was to document when oil field workers first began seeing ravens in the oil fields, as well as their observations of sites used for nesting over time. Given the increase in infrastructure and human activities in the oil fields over the last 40 years, I also wanted to document workers' perspectives on changes in raven abundance during this time period. This information will be useful for wildlife managers and biologists to predict how ravens respond to increased oil and gas activities across the North Slope.

Secondly, I sought to document workers' perspectives on the seasonal abundance of ravens to gain insight into ravens' use of the oil fields throughout the year. In addition to documenting use of structures and anthropogenic food sources during the breeding season, I also wanted to know how ravens used the oil fields during winter. It is presumed that ravens that remain on the North Slope during winter are entirely dependant on anthropogenic food resources because natural food availability is low and weather conditions are extreme.

Third, ravens in the oil fields are viewed as subsidized predators by wildlife managers and may require some form of population reduction in the future. I wanted to describe how oil field workers characterized and valued ravens, as well as their reactions to the idea of reducing the raven population.

Key Words: local knowledge, ravens, oil field workers

Background of the Oil Fields and Oil Field Workers

This study involved oil field workers from the two largest producing oil fields on Alaska's North Slope (Appendix 2.2): Kuparuk (103,396 ha, operated primarily by ConocoPhillips Alaska Inc. and BP Exploration (Alaska) Inc.) and Prudhoe Bay (122,595 ha operated by BP Exploration (Alaska) Inc.). Flanked by the Colville and

Sagavanirktok rivers, these oil fields were characterized by a network of buildings, pipelines, and gravel roads that spread extensively across wetlands and tundra (Truett and Johnson, 2000). Construction of the oil fields began in 1970 in Prudhoe Bay, after oil was discovered there in 1968 (National Research Council, 2003). Much of Prudhoe Bay's eastern region was developed first, followed by its western area and Kuparuk (Appendix 2.3). By 1983, roughly half of the structures that currently exist in this area had been built (Appendix 2.4; National Research Council, 2003). The current infrastructure footprint (gravel pads with structures, roads, airstrips, and exploration sites) of both oil fields, including smaller satellite oil fields to the east and west and nearby off-shore islands, was roughly 3670 ha (National Research Council, 2003). Most structures in Kuparuk and Prudhoe Bay were modular buildings, consisting of processing facilities, drill sites, and camps where workers were housed. Processing facilities were the largest structures (40-60 m tall; Backensto and Powell, 2010) and were not nearly abundant as drill sites. Drill sites were made up of one or two small buildings (5-15 m) connected to several well houses situated on a gravel pad (Backensto and Powell, 2010). Adjacent to Prudhoe Bay was Deadhorse (Appendix 2.2), an 'industrial town' that serviced the oil fields, which was characterized by warehouse buildings and camps. In 1978, a permanent landfill was established in Prudhoe Bay to service the oil fields and Deadhorse (J. Singleton, Service Area 10 North Slope Borough, pers. comm.). Oil companies began managing food wastes in the mid-1990's to reduce accessibility to wildlife by outfitting food dumpsters with lids and transferring wastes to the landfill in Prudhoe Bay (R. Shideler, Alaska Dept. of Fish and Game, pers. comm.).

There were roughly 3000 workers stationed in the oil fields (ConocoPhillips Alaska, Department of Health Safety and the Environment, pers. comm.) during the years of this study (2005-2006). Most workers spent roughly half of each year living and working in the oil fields. They worked shifts of 2-3 weeks at a time in the oil fields and then left for equal amounts of time to reside elsewhere in Alaska, the United States, or other parts of the world. Their typical work day was 12 hours long, beginning or ending at around 0600. The oil fields were in operation 24 hours a day, 7 days a week. After work, people generally retired to “camps” within the oil fields for eating, recreating, and sleeping.

I encountered numerous workers who expressed a personal interest in the local wildlife 2004-2007. Some were avid wildlife photographers, others were hunters and trappers, and some were Alaska Natives living active subsistence lifestyles in their home villages.

METHODS FOR DOCUMENTING OIL FIELD WORKER KNOWLEDGE

I used focus group and individual interview techniques in combination with a questionnaire to document local knowledge of oil field workers. Mixed method approaches like this are commonly used in social science to strengthen inferences with deductive and inductive modes of inquiry and analysis (Patton, 1987; Teddie and Tashakkori, 2009). I conducted focus group and individual interviews in the first year of the study (2005) to gain a broad and in-depth perspective of workers' knowledge of ravens. In the early stages of this study, I intended to use only focus group interviews; however, logistical constraints made it difficult to assemble groups for interviews and I also conducted individual interviews. In 2006, I distributed a short questionnaire to increase participation in this study, obtain quantifiable results, and systematically relate workers' backgrounds to their knowledge of ravens in the oil fields.

Interviews

Focus group interviews are an efficient way to collect qualitative data with a small group of participants. The purpose of this approach is to gain a broad and deep understanding of a particular topic using focused questions in a setting that allows participants to respond to questions, and to make additional comments after hearing other participant's responses (Patton, 1987; Krueger and Casey, 2000). I used a semi-structured approach for these interviews with a focus group script of open-ended questions to guide the interviews. This approach allows participants to discuss, at length, topic areas of most interest and relevance to them (Clark et al., 1994; Minnis et al., 1997; Krueger and Casey, 2000). I documented workers' observations of historical nests sites, perceptions of change in raven abundance, seasonal use of anthropogenic resources (food and structures), nesting activities, and personal characterizations of ravens (a copy of the focus group script and interview questions appears in Appendix 2.5).

In 2005, I conducted six focus group interviews, ranging from 2-11 participants per interview, for a total of 40 participants from across Kuparuk and Prudhoe Bay. I also conducted four semi-structured individual interviews with workers from across Kuparuk and Prudhoe Bay in a manner similar to the focus group interviews; the same open-ended questions were used to guide the individual interviews. Each interview (focus group and individual) lasted approximately one hour. Participants completed a biographical survey during this process (Appendix 2.6).

Audio-recording was used for all interviews in Prudhoe, but written notes were taken for those in Kuparuk because permission to audio record interviews there was not granted by the managing company. I conducted interviews by myself, which made it extremely difficult to simultaneously take notes and facilitate group interviews in Kuparuk. Focus group interviews are commonly conducted by more than one individual where one individual acts as the facilitator and the other takes notes on what's being said and the process as it is unfolding (Krueger and Casey, 2000). This is especially important when interviews are not audio recorded, as was the case for all interviews in Kuparuk. Given these limitations, I feel that the transcripts for Prudhoe interviews were of higher quality than Kuparuk transcripts. Audio recordings were not archived.

Although more interviews were conducted in Prudhoe, focus groups tended to be larger in Kuparuk, due in large part to certain restrictions placed by employers on when interviews could be conducted. For instance interview times in Prudhoe were limited to after participants' 12-16 hour shift, whereas in Kuparuk time was allocated at the end of staff meetings during work hours. In four instances only one person was available to participate in the focus groups; in those cases, I conducted individual interviews. Focus group interviews differed from individual interviews in process and outcome and likely yielded different results. For example, discussions in group interviews largely reflected group dynamics, which varied among interviews. In some groups, all participants participated, while in others certain individuals dominated the discussion. Individual interviews by contrast, provided ample time and space for each participant to discuss ravens at length; however, this process lacked the dynamics found in group discussions that in many cases prompted individuals to recall specific observations or events.

Questionnaires

Questionnaires are an effective and efficient way to collect and quantify specific qualitative data (Patton, 1987). I used this approach to quantify worker's knowledge of ravens and to relate their work history and experience to their knowledge of ravens. In the summer of 2006, I distributed 400 short questionnaires among staff at ten processing facilities and two contractor offices across Kuparuk and Prudhoe (Appendix 2.7). There were more processing facilities in Prudhoe; therefore, more questionnaires were distributed in this region of the oil fields. Questionnaires included multiple choice, short answer, and open questions about ravens allowing for longer answers. Of the questionnaires that were distributed, 12% were returned, two of which were completed by individuals who had previously been interviewed.

Interview and Questionnaire Participants: Biographical Details

Working with key informants is considered an important aspect of collecting local knowledge because they are known to be knowledgeable about a particular topic area and can provide trustworthy information (Davis and Wagner, 2003). However, identifying key informants is in itself a lengthy part of the research process that requires time to develop relationships and trust with members of a community. I did not target key informants for the interview process or when distributing questionnaires, but instead invited participation in the interview process through the use of flyers distributed widely among processing facilities and camps throughout the oil fields. I also solicited participation for interviews and questionnaires by alerting all personnel at safety meetings held regularly at processing facilities. Participation in this study was voluntary, and as such my sample is a small fraction of the oil field worker community and represented only those workers who were available or had an interest in the study or an interest in ravens. Additionally, I was a familiar person with all groups and the individuals interviewed. It is possible that the participants recruited for this study were only those with whom I had a favorable relationship, while other knowledgeable individuals were deterred from participating.

It was necessary to quantify workers' observations relative to their experience working in the oil fields and the spatial extent of their work activities. Local knowledge is often unevenly distributed within a community, and observations about ecological phenomena are made at various temporal and spatial scales (Olsson and

Folke, 2001; Ghimire et al., 2004; Roth, 2004; Gilchrist et al., 2005; Chalmers and Fabricius, 2007). Likewise, acknowledging and describing the context of local knowledge is an important consideration for its integration with scientific knowledge because it enables researchers to address biases and misinterpretations and to locate commonalities among sources of information (Usher, 2000; Agrawal, 2002; Brook and McLachlan, 2005; Heiskanen, 2006; Huntington et al., 2006; Gilchrist and Mallory, 2007).

To relate workers' backgrounds to their knowledge of ravens, I categorized workers into one of three job type categories that reflected the spatial domain of their work activities: 1) facility operators, 2) drill site operators, and 3) field operators. While these categories do not encompass all job types in the oil fields, they are relevant for participants in this study. Facility operators worked primarily at a processing facility in either Kuparuk or Prudhoe. In general, facility operators worked entirely within the perimeter of the gravel pad on which the facility was situated. Some of these operators spent more time working outside of the buildings than others, but I was unable to characterize individuals in this way. Drill site operators worked across a specific area of either Kuparuk or Prudhoe that encompassed several drill sites. These drill sites were generally grouped around a major processing facility, and drill site operators traveled between them and typically conducted much of their work from pick-up trucks. Field operators generally covered larger areas than drill site operators, usually in either Kuparuk or Prudhoe, but in some instances across both. Workers in this category were fairly diverse in the type of work they did, but all worked at multiple locations and in some cases they stayed at particular locations for extended periods of time. Workers were also assigned to one of three categories to represent the number of years they had worked in the oil fields: <10, 10-19, and ≥20.

Focus group and individual interviewees were primarily drill site operators (48%), whereas questionnaires were primarily completed by facility operators (51%, Fig. 2.1). Slightly more workers from Prudhoe (54%) participated in the interviews than those from Kuparuk (45%, Fig. 2.1), but focus groups tended to be larger in Kuparuk. More questionnaire respondents (69%) worked in Prudhoe than in Kuparuk.

Longevity in work history was a common characteristic of interview and questionnaire participants. Of the workers I interviewed, most (77%) had worked in the oil fields for 10 or more years, of which 42% had worked there 20 years or more (Fig. 2.1). Most questionnaire respondents (72%) worked in the oil fields 10 or more years, of which 80% had worked there 20 years or more (Fig. 2.1). I did not collect data on the number of weeks each participant spent in the oil fields during each stay, but in general they worked 2-3 weeks at a time with a similar amount of time spent away from the oil fields.

Focus Group and Individual Interview Content Analysis

I transcribed audio recordings and notes from interviews and used a qualitative software program (Atlas ti 5.5, 2008) to code and summarize the content of transcripts. Content analysis is a process by which the statements of interviewees are ascribed to codes in an “open coding” process (Gorden, 1992; Charmaz, 2006). In this analysis codes were generated from the narratives of workers to create a common list. I then grouped statements by code and summarized material within themes (Table 2.1). Themes were subcategories of broader topic areas of research interest that conveyed the general content of interviewees' statements that were defined prior to and during the coding process (Table 2.1).

The difference between Kuparuk and Prudhoe transcripts made it difficult to compare information from all interviews and limited my ability to generalize workers' knowledge. For example, I was unable to link quotes to individual participants for Kuparuk focus group interviews. Additionally, I was unable to summarize workers' observations relative to their backgrounds for interviews because linking biographical information with statements in most interview transcripts was rarely possible, especially for interviews that were not audio-recorded.

Questionnaire Analysis

Questionnaire responses were cataloged in Microsoft Access and summarized by the frequency of responses for multiple choice and short answer questions. Long answers were coded similarly to interview transcripts. I summarized responses for the overall sample of respondents, and in order to relate workers' work experience in the oil fields to their observations of ravens, I stratified responses by job type, region worked in (Kuparuk and Prudhoe), and length of time worked in the oil fields. Responses were summarized within the same thematic framework as the interviews. Questionnaire participants are referred to as 'respondents' to distinguish their responses from interview participants. There were two respondents for which biographical details were left blank on the questionnaires for either job type or longevity; therefore, I excluded them from stratified summaries.

Integration of Interview and Questionnaire Results

I summarized interview and questionnaire results together to describe the content of oil field workers' knowledge of ravens for five main topic areas: 1) population characteristics, 2) use of structures, the landfill, pick-up trucks, and dumpsters by ravens 3) ravens' responses to human activities, 4) worker perspectives of ravens as predators, and 5) perspectives and personal relationship with ravens. Though results from interviews and questionnaires are fundamentally different and lend themselves to different types of analysis (Patton, 1987), I chose to summarize them together for each topic area. Presenting them in this way allowed me to describe the content of oil field worker knowledge and a context of workers observations based on characteristics of their work experience.

FINDINGS

Raven Population Characteristics

Oil field workers provided historical perspectives on the resident raven population and information about the number and location of nest sites in the oil fields. The earliest report by interviewees and respondents of seeing ravens in the oil fields was at the Discovery Well in Prudhoe Bay in 1966. Most early reports of workers seeing ravens in the oil fields were from Prudhoe Bay, during the beginning of oil production (1975-1977). At Kuparuk, where construction began after Prudhoe Bay started producing oil, workers first observed ravens in 1981, often near dumpsters which were uncovered before food management policies were implemented. The earliest report of a raven nest in the oil fields was 1971 at Flow Station 2, a processing facility in eastern Prudhoe. In all, 32 individual locations were identified by workers as nest sites (Fig. 2.2). These nests were placed on processing facilities, drill sites, and bridges; nine were located on structures that ravens did not use for nesting during the breeding ecology study conducted from 2004-2007 (Backensto and Powell, 2010). Processing facilities were consistently reported to be used as nest sites for the longest periods of time; five were used as nest sites for more than 20 years (Fig. 2.2), three of which were first used in 1980. Drill sites were described in the interviews as the more recently and variably used sites for nesting, dating back to the early 1990s; five were on drill sites that were not used during my study.

Most workers perceived an increase in the population of ravens in the oil fields (Table 2.2). In all interviews workers talked about seeing more ravens over the years, but their perceptions about the size of the increase varied from “a little more” to “double.” Most respondents (62%) indicated the population increased, of which 40% indicated it was substantial (>26%), whereas 60%, indicated the increase was “small”. Differences in perceptions of raven abundance were related to workers’ backgrounds. Most field operators and workers with a shorter history in the oil fields (<10 years) reported the increase was "small" (Table 2.2). Perceptions about the magnitude of increase were most similar for facility and drill operators, and for workers in Kuparuk and Prudhoe (Table 2.2). Two long time workers (≥20 years) commented in interviews that early in the oil fields' history, before food waste policies were implemented, wastes were more exposed and abundant, which attracted a lot of scavenging animals including ravens. These same workers, who worked in Prudhoe near the landfill, also indicated that at that time, while fewer ravens were seen at the landfill, ravens were abundant throughout the oil fields. One long-time landfill employee (≥20 years) said he observed more ravens at the landfill within the last few years.

It was unclear whether oil field workers noticed more ravens in winter, with the exception of landfill employees. Prudhoe interviewees saw more ravens in winter and attributed the increase to ravens looking more actively for food during that season. They also noted that ravens were easier to see in the winter. One person said ravens returned to his facility each year "only after winter sets in, after the snow flies." The two workers who operated the landfill talked about seeing more ravens in winter than any other season, about 40 ravens on average, depending on daily weather conditions. They indicated on clear, calm winter days ravens were present before they started working on the active face; "once those lights come on, they really tend to come in." They observed that raven numbers noticeably declined at the landfill in "middle to late May, around the end of break-up, when the other birds like gulls and snow buntings come in." Few respondents (25%) observed more ravens in winter.

Overall, Kuparuk interviewees did not notice a seasonal difference in the number of ravens, but some indicated they might see more in summer because of nesting pairs in their work areas. Landfill workers noticed fewer ravens during summer, and mentioned that when they saw ravens during summer there were more in the morning, but when their work activities began each day and the gulls came in, most would disappear. Roughly half (53%) of the respondents observed more ravens during summer (Table 2.2). Respondents who observed more ravens during summer, relative to their respective categories, were primarily facility or drill site operators, long time employees (≥20 years), or those who worked in Kuparuk (Table 2.2).

Raven Use of the Landfill, Structures, Dumpsters and Pick-up Trucks

Workers discussed the landfill, structures, dumpsters, and pick-up trucks as aspects of the oil fields used by and important to ravens. Seasonal variation in their use by ravens was most pronounced for the landfill and the processing facilities near it in eastern Prudhoe Bay. Prudhoe workers from both the interviews and questionnaires identified six processing facilities and two drill sites within 5 km of the landfill as areas where ravens congregated during winter. Large roost flocks (20-50 ravens) were observed most notably at one facility (FS1, Fig. 2.2) and smaller groups (<10) were observed at two other, nearby, processing facilities. Some interviewees, who worked at or near these facilities where ravens congregated, mentioned that during winter ravens headed to the landfill daily and returned to these facilities at dusk. A little more than half of the respondents (53%), most of which had worked more than 10 years the oil fields, indicated seeing congregations of ravens in the winter (Table 2.3).

Workers also described characteristics of processing facilities and drill sites used by ravens. In almost every interview, workers linked heated structures on these facilities with their observations of ravens. Heated features associated with all types of buildings were discussed in all interviews as being used such as exhaust vents, heat traced pipes, lights, heat stacks, fin fans of dew point coolers, gas to liquid heat exchangers, line heaters, and gas flares. They also indicated that these features were an important source of heat for ravens during winter and were locations for nests. Workers perceived these features provided ravens with a warm environment, protected from the wind. Some workers emphasized that heat produced by processing facilities was far greater than at drill sites, and this might explain ravens' preference for processing facilities during the summer for nesting and winter for roosting. Most respondents (71%) frequently observed ravens at processing facilities in the winter (Fig. 2.3). Additionally, in all interviews, workers indicated that complexity and height of processing facilities was important to nesting ravens because some building features (landings, modules, stairways, pipe racks, and gas flares) provided safety for recently fledged young and were platforms from which fledglings practiced flight. Pipe racks on processing facilities and well houses at drill sites were described during interviews as locations where ravens were observed caching food items or where caches were found. However most respondents (67%) did not observe ravens caching food and of those who did, most were facility operators or long time workers (≥20 years, Fig. 2.4).

Dumpsters and pick-up trucks also emerged in all interview discussions focused on how ravens use the oil fields. Workers talked of often seeing ravens collecting nesting materials at dumpsters, including welding rods, road delineators, nine-wire, strips of metal banding, survey sticks, rubber, fiberglass, insulation, reflectors, pipe blanket insulation, and corrosion tubing. They also observed ravens perched at or near covered food dumpsters and inspecting beds of pick-up trucks. As one worker indicated, "Don't try to put a bag of garbage in the back of your truck." Some workers talked about ravens occasionally entering the truck cab through open windows. "Ravens removed a lunch sack from a backpack located inside the drill site truck, removed the plastic wrap from the sandwich, tossed aside the bread and ate the meat." Most questionnaire respondents observed raven activity at dumpsters (85%) and trucks (81%), but it wasn't clear whether interviewees or respondents saw this more in winter or summer. Less than half of respondents indicated winter was the most common time to observe raven activity at dumpsters (48%) or trucks (39%, Fig. 2.5 and Table 2.3); the remaining responses were split between summer, year round, and not having observed ravens under these circumstances (Fig. 2.5). Drill site operators and those with a 10-19 year history in the oil fields were more likely to observe these activities during winter than other workers (Table 2.3).

Raven Responses to Human Activities

Workers observed that ravens responded to changes in human activity. They commonly observed ravens at facilities and drill sites when human activity was high, such as during drilling rig activity and construction projects. Although this was observed throughout the year, interviewees said they saw more of this during the winter, whereas during summer ravens were more commonly seen on the tundra. Roughly half of the respondents reported it was common to see ravens at drill sites with drilling rig activity during winter (51%) and summer (50%; Fig. 2.6). Drill site operators and Kuparuk workers were more likely than other workers to observe ravens at drilling rig activity (Table 2.3). Ravens at the landfill responded differently to human activity, according to landfill workers. They observed that ravens were more wary and disturbed by human activity at the landfill during summer, whereas during winter when activity was lessened, they were "more curious and willing to ride around on the loader looking into cab." Some workers believed that ravens differentiate between short- and long-term worker activities and that ravens learned the schedules and routines of specific workers, especially those who managed food wastes.

Perspectives of Ravens as Predators

In half of the interviews, workers talked about ravens as predators of nests, birds, and small mammals during the summer. Some workers described ravens harassing waterfowl off their nests, sometimes working in pairs, and taking eggs or young from the nest. Another worker described watching adult ravens teaching their young to prey on waterfowl nests. Workers also observed ravens on the tundra digging up lemmings. One worker said he frequently witnessed bears and foxes predating bird nests, and he believed they did this more often than ravens. Others, who did not observe ravens behaving as predators still believed they were predators, because they often found the remains of eggs, birds, and rodents on buildings where ravens were nesting or in and around nests. Only 38% of respondents reported seeing ravens with eggs, whereas 53% of respondents observed them with birds or small animals. Drill site operators, long time workers (≥20 years), and Prudhoe workers were the primary observers of predation activities relative to other workers in respective categories (Fig. 2.7, Fig. 2.8).

Workers' Perspectives and Personal Relationship with Ravens

Workers expressed a wide range of perspectives about ravens and talked about their personal relationship with the birds. Almost every interview participant characterized ravens as intelligent birds and many referred to ravens as a culturally symbolic animal. Stories of ravens demonstrating intelligence by learning human activity schedules, evaluating opportunities, and interacting with humans accompanied many descriptions of raven intelligence. In most interviews, workers acknowledged the significance of ravens as a cultural symbol for Alaska Natives. Two workers specified that coastal Tlingit and interior Athabaskan Natives viewed ravens as spiritual figures and thus commanded respect. In contrast, these respondents reported that Iñupiat Eskimos viewed ravens as pests, and they believed that ravens held little to no cultural significance for this culture group. The cultural and spiritual significance of ravens was further explained as a result of how humans connected with ravens, such as the way ravens participate in hunting activities or that people recognize the ability of ravens to learn quickly.

Many of the workers who participated in this study expressed their admiration of ravens and often shared personal feelings regarding ravens, yet they also raised issues about how ravens interfered with work activities and the ways in which ravens created health and safety concerns. Many workers respected and admired ravens because of their ability to remain in the oil fields throughout the winter when weather conditions were harsh and food was limited. Sentiments of pride were expressed about one resident nesting pair at a processing facility in Prudhoe:

> "I would say everybody's proud of them, and that's [proud] a bad word, but everybody says 'they're back, where's the nest, how many are in the nest?' and a lot of people come back from 2 weeks off and the first thing is 'have they hatched?', not 'are we still up or are we still down [barrel production]?'"

Respondents characterized ravens in similar ways, and most conveyed positive attitudes about ravens (Fig. 2.9).

Not all workers respected and admired ravens. One individual was concerned about ravens as predators because he perceived that they had expanded their northern range in Alaska and had increased in number. This same person referred to ravens as competitors of other native avian predators:

> "If they're eating all [that] the jaegers, foxes, snowy owl [eat] and whatever eats the mice, the ravens are flying competitors for them that's never been there, they

eat pretty crazy, they're hungry," "it's[the population of ravens] going to put an imbalance on the food chain".

A few respondents shared similar ecological perspectives or expressed perspectives about a need to manage ravens.

Although positive attitudes and perspectives about ravens were more frequently expressed, people did not hesitate to also talk about how ravens interfered with their work or to express their frustrations and concerns. From a production standpoint, ravens created work delays for individual workers and entire facilities, and also presented health and safety concerns for workers. Work delays were the most common form of interference described in the interviews, and 34% of respondents indicated ravens caused work delays or interference. In one focus group interview, workers told of an incident in 1984 when a raven moved welding rods to its nest at a power substation and was electrocuted, causing a loss of power and shutdown to one processing facility and several drill sites. In another interview, an individual described a project delay caused by a raven family that followed him as he flagged a pipeline; the ravens removed the flagging after he placed it, which forced him to redo the flagging. Some workers expressed frustration with ravens because they responded quickly to trash bags in the bed of trucks that were in route to appropriate receptacles. Others talked about being fearful of aggressive ravens or experiencing discomfort when working in nesting areas. Some workers expressed health concerns about the accumulation of raven feces at the main winter roosting facility (FS1) in Prudhoe Bay. Nesting materials were discussed by one individual, who viewed them as a corrosion problem and electrical fire hazard because of where nests were located on processing facilities.

Workers' Perspectives on Managing Ravens

Interviewees varied in their reactions to the general concept of "managing ravens" and only a small proportion of questionnaire respondents (14%) indicated management directed towards reducing the raven population was necessary. In two interviews, several workers, Alaska Native and non-native, emphasized that managing ravens would bring bad luck, a bad omen, and "going against the spirit of the raven." In two interviews workers commented that interfering with ravens was not necessary because they 'like [ravens] and they aren't bothering anyone." One individual mentioned the heated conversations he had with coworkers about dealing with ravens and he said, "Some people would be hostile" about controlling populations (e.g. removing them or destroying nests) "because they are sympathetic to [ravens]." In spite of his understanding of the conflict, he personally felt that managing ravens was necessary because he believed that ravens were not native to the area. Others were more ambivalent; one worker said, "It depends on who you ask, like someone who forgot their garbage in their truck." Two individuals emphasized the type of management action taken would determine how most people in the oil fields would react to managing ravens.

Workers discussed nesting deterrents, lethal control, and sterilization as ways to reduce the raven population. In general, they felt that it was infeasible to modify structures in the oil fields to deter ravens from nesting. However, some interviewees suggested: 1) applying netting or wires to structures, 2) removal of nests, and 3) hazing ravens during nest building. A few individuals suggested lethal actions were necessary to reduce the number of ravens in the oil fields. Another individual suggested sterilization of breeding adults as a less controversial option.

DISCUSSION

Workers have had direct experience observing and interacting with ravens, and demonstrated through their responses that they hold ecological knowledge of the raven population in the oil fields. Experiential knowledge like this is a quality of local knowledge that helps researchers gain insight into local conditions to refine hypotheses and redirect scientific inquiry (Schmidt, 1993; Nabhan, 2000; Olsson and Folke, 2001, Huntington et al., 2004a; Gilchrist et al., 2005; Bart, 2006). Interview and questionnaire work with oil field workers yielded information about ravens in the oil fields that filled knowledge gaps in the history of ravens in this area and complemented existing data about raven use of anthropogenic and natural food sources (Table 2.4). New information about historical nest sites and winter activities of ravens, in conjunction with insights about characteristics of structures used for nesting and raven responses to human activities in the oil fields, contributed to the development of hypotheses regarding nest site use (Table 2.4; Backensto and Powell, 2010). New insights into management concerns of ravens in the oil fields were gained from workers' personal perspectives about ravens (Table 2.4).

Historical Information and Population Change

One primary objective of this study was to acquire historical information about ravens in oil fields, specifically their use of structures for nesting. Workers provided observations of historical nest sites in the oil fields that preceded the earliest records of nest site use made by other biologists by 15 years, and indicated that ravens started nesting in the oil fields immediately after large structures were first established in 1970. Workers with a long history working in the oil fields provided historic nest site locations. Observations about the types of structures ravens nested on, the duration of nest site use, and insights about heated features on structures and their use by ravens were important in shaping testable hypotheses about nest site use and interpreting results from this analysis (Backensto and Powell, 2010). Their observations suggested that this population immediately responded to and utilized human structures once they were available, much like raven populations in Idaho and Oregon that began nesting on transmission towers one year after they were constructed (Steenhof et al., 1993).

Another objective of this study was to expand on existing background information about change in raven abundance in the oil fields over time and to provide information about seasonal abundance. Workers' perspectives on these topics varied a great deal, and it was difficult to generalize whether the population had increased or whether ravens were more abundant in winter or summer; however, most workers perceived that the population had increased overall. Some perspectives about changes in raven abundance suggest that oil companies' policies regarding food wastes have effectively restricted raven access to anthropogenic food, except at the landfill where ravens are abundant, especially during winter.

Assessing changes in raven abundance may have been difficult for workers for several reasons. Job type and/or work location may partially explain their variable responses about the magnitude of population change. For example, facility and drill site operators primarily observed ravens that nested or over-wintered at their work sites; therefore, they observed a smaller segment of the entire raven population than did field operators. This may explain why facility and drill site operators observed more ravens during the summer, due to the presence of breeding pairs and young ravens. Field operators by contrast observed a larger portion of the population, and may have a better sense of fluctuations in raven numbers over time and seasonally.

Winter Resources, Trucks, Dumpsters, Human Activities, and Ravens as Predators

This study also focused on gaining additional insight into how anthropogenic food sources, structures, and human activities in the oil fields subsidize the resident raven population throughout the year. Workers provided new information about raven winter activities; use of the landfill and winter roost sites were noteworthy examples. Landfill workers observed greater numbers of ravens at the landfill over the course of the winter, resembling numbers from more recent CBC counts (Appendix 2.1). Workers also identified a processing facility (FS1) that served as a winter roost site near the landfill for as many as 50 ravens, suggesting that there are more ravens in

Prudhoe than Kuparuk during winter. Workers' insights and interpretations about use of heated features by roosting ravens at FS1 and other processing facilities suggest that heat sources are important to ravens during winter. Their observations about raven movements between this roost site and the landfill resembled a pattern observed elsewhere for ravens moving between roosts and large food bonanzas (e.g. landfills) in California, Canada, Germany, Mediterranean islands, and Fairbanks, Alaska (Heinrich, 1988; Watts et al., 1991; Sara and Busalacchi, 2003; Preston, 2005; Boarman et al., 2006; Janicke and Chakarov, 2007; R. King, USFWS pers. comm.; F. Huettmann, UAF pers. comm.). Winter activities such as roosting at FS1 and use of the landfill were observed primarily by workers at or near those sites, which may explain why overall workers' perspectives on seasonal abundance varied. For example, field operators were divided about seasonal abundance of ravens because most were based in Kuparuk where large raven roosts and congregations did not occur.

Workers provided additional evidence that ravens find food in pick-up trucks and dumpsters, and new information about how ravens respond to human activity in the oil fields. However, their observations did not yield much information about the seasonal occurrence of these behaviors. Regardless, their observations, in conjunction with Powell and Backensto (2009), suggested that ravens key into pick-up trucks and dumpsters for food despite food waste management regulations. Workers also observed that dumpsters filled with industrial materials were a source of nesting materials for ravens. These materials may be a potentially important subsidy considering that sticks, a common nest material for ravens elsewhere (Boarman and Heinrich, 1999), are limited in this environment.

According to workers, ravens investigated and responded to increased human activity in the oil fields, suggesting they associate human activity with food. Other researchers studying ravens in Wyoming, the Mojave Desert, and Germany have suggested that ravens respond to specific types of and changes in human activities to locate food (Storch and Leidenburger, 2003; White, 2005; Boarman et al., 2006). For example, Boarman et al. (2006) observed that raven abundance was positively associated with human abundance at a cantonment in the Mojave Desert and fluctuated with troop rotation schedules. Job type and regional location of workers may explain why I was unable to determine if workers observed a seasonal difference in these raven behaviors. For example, drill site and field operators were probably more aware of raven activities at pick-up trucks and in response to human activity because they regularly traveled between areas where drilling or construction occurred. Assuming ravens do associate drill rig activity with foraging opportunities, workers in Kuparuk may see ravens at drill rigs in the winter more than did Prudhoe workers because the landfill was farther away. Another explanation for these observations may be that rig activity is higher in Kuparuk than Prudhoe.

Workers observations and perceptions of ravens as nest predators of tundra-nesting birds supplemented my observations of raven foraging activities during their breeding season. Ravens preyed on nest contents (eggs and chicks) of ground-nesting species as well as on small mammals during the summer months (May-August; Powell and Backensto, 2009). However, most workers did not observe raven predatory behavior. Those who did were primarily drill site operators, who probably had better visibility of breeding pairs foraging around their nests and thus more opportunities to observe predatory activities than other workers. In addition, more experience working in the oil fields and thus more time to observe ravens in this environment may explain why workers with more than 20 years of experience observed ravens with prey items more frequently than other workers.

Workers' Personal Values of Ravens in the Oil Fields

I explored personal perspectives about ravens and raven management to understand better the range of values workers have regarding ravens that may affect future raven management actions. Many workers interacted with and had a personal connection with ravens. Ravens interfered with activities; thus workers expressed concerns about ravens in their work areas that highlighted issues and problems with ravens in the oil fields. Similar to other cultures and societies, many workers characterized ravens as intelligent and revered creatures (Nelson, 1983; Smelcer, 1991; Marzluff and Angell, 2005b). Some workers also expressed negative sentiments about interfering with ravens that suggests management of ravens in the oil fields will be a controversial topic, especially at specific locations. Interactions with ravens may have resulted in the cultural, spiritual, and management-related perspectives workers hold about ravens in the oil fields. Marzluff and Angell (2005a) suggested that interactions between corvids and humans facilitate a process they refer to as "cultural co-evolution"; this process explains how other cultures have developed spiritual and cultural connections with ravens. Interactions between workers and ravens warrants further exploration and may improve our understanding of how ravens adapt to changing conditions in this environment, such as the enforcement of food management policies.

Future Research Considerations

Davis and Wagner (2003) suggested that identifying and characterizing local knowledge involves specification of the knowledge domains and the domain of inquiry. The findings of this study clearly demonstrate that including oil field workers as part of a North Slope observation system is an idea worthy of consideration. The domains of oil field workers' knowledge of ravens appear to be defined by their experiences in the oil fields; therefore, future research should consider observer qualities as key perspectives and refine inquiries to target knowledgeable individuals with these perspectives. For example facility operators should be asked questions about raven nesting activities where they work, instead of questions about raven activity at drill sites. Likewise, drill site operators should be targeted to answer questions about ravens nesting and foraging at drill sites, and raven activities in their work areas throughout the year. Field operators should be asked large-scale questions about raven activities because they generally observed a larger segment of the population. Prudhoe workers, especially those near the landfill, could be targeted for information about the winter population roosting near the landfill. Historical questions about the raven population should be directed to workers with more than 10 years of experience working in the oil fields. Focusing inquiries in this way will improve efficiency of research efforts and yield more specific information about raven ecology in the oil fields.

Future efforts should also consider using focus group interviews and questionnaires to document local knowledge. Focus groups, like individual interviews, were an important method for capturing detailed observations, insights, and personal perspectives about ravens in the oil fields and provided a way to explore their depth of knowledge. In addition, focus groups are a more efficient way to interview multiple workers at once. Although questionnaires were useful for gathering specific information, quantifying responses, and identifying relationships between experience in the oil fields and worker knowledge, they restricted observations to discrete responses, essentially eliminating the rich detail found in narratives of interviews (Patton, 1987). Questionnaire responses also supplemented and confirmed results obtained from interviews about historical nest sites, perceptions of population increase, and observations of large groups of ravens at facilities in Prudhoe during winter. However, questions regarding seasonal abundance and use of infrastructure had as many as 25% of respondents indicate they were unsure. Questionnaires can be biased instruments in a number of ways, one of which results from misleading questions or wording (Patton, 1987; Oppenheim, 2001). The wording of parts of my questionnaire may have been too limited, general, or confusing to answer and possibly influenced the way some workers chose to answer questions. I conducted a brief pre-test of the questionnaire, to identify problematic areas, but I suspect it was not substantial enough to adequately refine it.

Finally, I did not include other potential sources of local knowledge about this population, primarily for logistical reasons. Future work should document the knowledge held by biologists that conduct surveys and studies in the oil fields, as well as that of the residents of Nuiqsut, the closest Native village to these oil fields. Incorporating others' knowledge of ravens in this area would likely improve our understanding of ravens in the oil fields.

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Table 2.1. Organizational framework of content analysis used to summarize transcripts from interviews with oil field workers about ravens, conducted in 2006 in the Kuparuk and Prudhoe Bay oil fields, Alaska. Oil field workers' statements were coded into topic areas.

Broad Topics about Ravens	**Themes about Ravens (Organization of Coded Observations)**	**Summary Topic Areas of Grouped Themes**
Population history and change in population size over time	• When and where ravens were first observed in the oil fields • Fluctuations in raven numbers over the years and throughout the seasons	• Population characteristics
Nests and breeding activities	• Historical nest sites and number of years used • Nest materials and nest building • Behavior of breeding adults • Building features nests were placed on • Insights about nest placement	• Population characteristics • Raven activities relative infrastructure • Ravens as predators • Personal perspectives and feelings about ravens
Seasonal raven activities and use of infrastructure	• Abundance in the summer and winter • Seeing near infrastructure and on a seasonal basis • Activities relative to infrastructure • Activities relative to human activities	• Population characteristics • Raven activities relative infrastructure • Response to human activities • Ravens as predators • Personal perspectives and feelings about ravens

Table 2.1 continued.

Broad Topics about Ravens	**Themes about Ravens (Organization of Coded Observations)**	**Summary Topic Areas of Grouped Themes**
Foraging Activities	• Seeing with human food and on a seasonal basis • Seeing with prey items and on a seasonal basis • Obtaining food • Interactions of ravens with other species • Caching behavior	• Raven activities relative infrastructure • Ravens as predators • Personal perspectives and feelings about ravens
Characterization and personal perspectives	• Personal feelings about ravens • Personal interactions with ravens • Acknowledgement of other cultural perspectives of raven • Attitudes towards ravens	• Personal perspectives and feelings about ravens
Issues and personal perspectives of management	• Interference with work activities • Perspectives on managing	• Response to human activities • Personal perspectives and feelings about ravens

Table 2.2. Oil field workers' perceptions of raven population change, magnitude of population increase, and differences in seasonal abundance of ravens in the Kuparuk and Prudhoe Bay oil fields, Alaska based on questionnaire responses completed in 2006. Responses were stratified by job type (FA- Facility Operators, DS- Drill Site Operators, and FI- Field Operators), number of years worked in the oil fields (years), and the oil field where workers were located (K-Kuparuk and P-Prudhoe Bay). Responses are represented as proportions of respondents in each stratification level. Sample sizes differ among stratification levels because background information was missing for some respondents.

Response	**Job Type (%)**			**Time in Oil Fields (%)**			**Region (%)**	
	FA	**DS**	**FI**	**>20**	**10-19**	**<10**	**K**	**P**
Population change †	$n = 23$	$n = 14$	$n = 9$	$n = 27$	$n = 7$	$n = 13$	$n = 15$	$n = 32$
Increasing	65	64	67	69	71	53	80	56
Staying the same	22	28	22	19	14	31	13	28
Decreasing	0	7	0	8	0	0	0	6
Magnitude of population increase	$n = 19$	$n = 9$	$n = 7$	$n = 20$	$n = 6$	$n = 9$	$n = 13$	$n = 23$
Major (>50%)	26	22	0	35	0	0	23	17
Significant (26-50%)	16	22	28	15	67	0	23	17
Small (<25%)	58	56	71	50	33	100	53	65
Seasonal abundance ††*	$n = 25$	$n = 14$	$n = 9$	$n = 28$	$n = 7$	$n = 13$	$n = 15$	$n = 34$
More in winter	28	7	33	36	14	8	20	27
More in summer	52	64	33	61	43	38	60	47

† 9% of all respondents answered unsure
††23% of all respondents answered unsure
* 2% of all respondents answered both summer and winter

Table 2.3. Oil field workers' observations of seasonal raven activity at drill sites with drilling rig activity, dumpsters, and pick-up trucks, as well as congregations in winter in the Kuparuk and Prudhoe Bay oil fields, Alaska, based on questionnaire responses completed in 2006. Responses were stratified by job type (FA- Facility Operators, DS- Drill Site Operators, and FI- Field Operators), number of years worked in the oil fields (years), and the oil field where workers were located (K-Kuparuk and P-Prudhoe Bay). Responses are represented as proportions of respondents in each stratification level. Sample sizes differ among stratification levels because background information was missing for some respondents.

Response	**Job Type (%)**			**Time in Oil Fields (%)**			**Region (%)**	
	FA	**DS**	**FI**	**>20**	**10-19**	**<10**	**K**	**P**
Drill sites with rigs	$n = 24$	$n = 14$	$n = 9$	$n = 27$	$n = 7$	$n = 13$	$n = 15$	$n = 33$
Winter	28	79	78	39	72	62	80	38
Summer	25	93	56	44	86	46	67	42
Dumpsters †	$n = 25$	$n = 14$	$n = 8$	$n = 28$	$n = 6$	$n = 13$	$n = 14$	$n = 34$
Winter	44	50	62	43	83	46	57	44
Summer	32	28	25	28	0	38	28	29
Trucks ††	$n = 24$	$n = 14$	$n = 9$	$n = 28$	$n = 6$	$n = 13$	$n = 15$	$n = 33$
Winter	25	57	56	32	67	46	47	37
Summer	17	14	44	18	17	31	40	12
Winter congregations †††	$n = 24$	$n = 14$	$n = 9$	$n = 27$	$n = 7$	$n = 13$	$n = 15$	$n = 33$
Yes	62	36	44	59	57	38	40	58
No	25	36	44	37	14	31	53	21

† 15 % of all respondents had not observed ravens at dumpsters
†† 17% of all respondents in Job Type and Time in Oil Fields and 19% of those in Region had not observed ravens at pick-up trucks
††† 17% of all respondents in Job Type and Region and 15% of those in Time in Oil Fields category answered unsure

Table 2.4. Summary of the insights into raven ecology in Kuparuk and Prudhoe Bay oil fields, Alaska gained from oil field workers' knowledge and their contribution to a raven study in the oil fields. Oil field workers' knowledge was documented in 2005 and 2006 with interviews and questionnaires.

Topic Area of Raven Ecology	**Insights Gained from Oil Field Workers' Knowledge**	**Contribution of Oil Field Workers' Knowledge to the Scientific Study of Raven Ecology**
Colonization of the oil fields	•History of nest sites •Dates ravens were first seen	•Filled knowledge gaps in historical observations of nest location and duration of nest site use •Provided the earliest observations of ravens in the oil fields
Historic changes in population abundance and distribution	•Perception of population change •Observations of ravens exploiting unmanaged food wastes throughout the oil fields	•Provided information about past raven distribution and activities relative to anthropogenic food sources
Seasonal abundance and distribution	•Perceptions about seasonal abundance •Observations of seasonal use of the landfill •Winter observations of congregations	•Complemented and expanded existing data about landfill use •Provided new information about winter activities
Importance of infrastructure to ravens	•Observations of nest sites •Observations and interpretation of nest placement •Interpretation about the role of heat in nest placement and use of structures in the winter as roost sites •Observations of nest materials and use of material dumpsters •Observations of pick-up trucks and dumpsters	•Aided in generating hypotheses about raven use of structures for nesting •Provided new information about nest materials and winter activities •Complemented observations of use of anthropogenic food sources

Table 2.4 continued.

Topic Area of Raven Ecology	Insights Gained from Oil Field Workers' Knowledge	Contribution of Oil Field Workers' Knowledge to the Scientific Study of Raven Ecology
Predatory behavior	•Detailed observations of nest predation and predation strategies •Observations of prey items •Perception of ravens as predators	•Complemented and confirmed observations of predation and foraging strategies
Human interactions with ravens	•Observations of raven response to human activities •Perceptions and interpretations about raven interactions with humans •Personal connection, values, and characterization of ravens	•Aided in generating hypotheses about human activities as a measure of anthropogenic food sources •Identified values and illustrated workers connection with ravens
Management and policy implications	•Observations and perceptions about raven interference with work activities •Reactions and values on acceptability of management alternatives	•Provided new and detailed information about management issues and concerns related to workers and production activities •Identified the need to consider the human dimensions of raven management

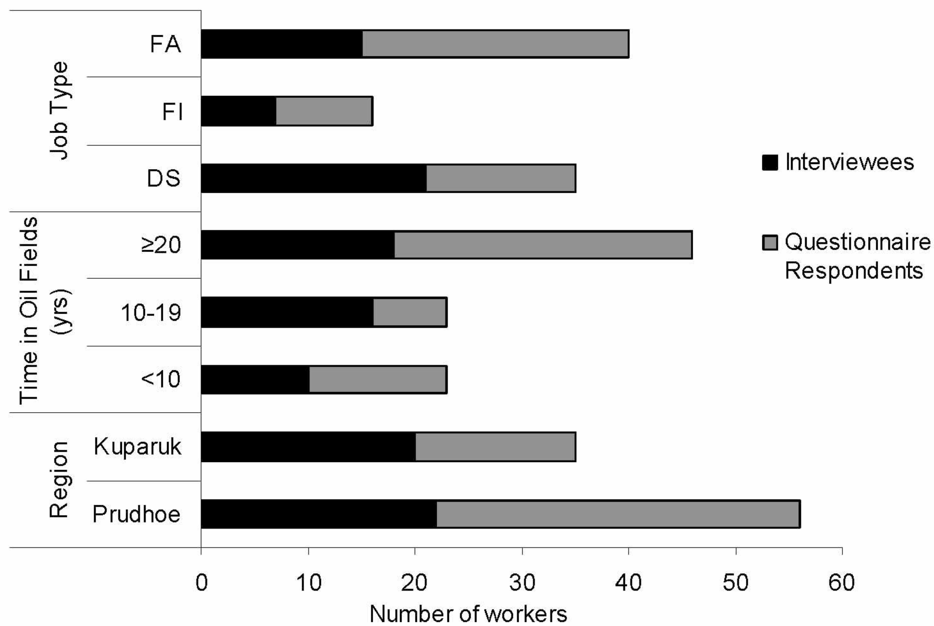


Figure 2.1. Biographical details of oil fields workers who were either interviewed or completed questionnaires about ravens in the Kuparuk and Prudhoe Bay oil fields, Alaska, 2006. Backgrounds of workers are summarized by job type (FA- Facility Operators, DS- Drill Site Operators, and FI- Field Operators), length of time working in the oil fields, and oil field.

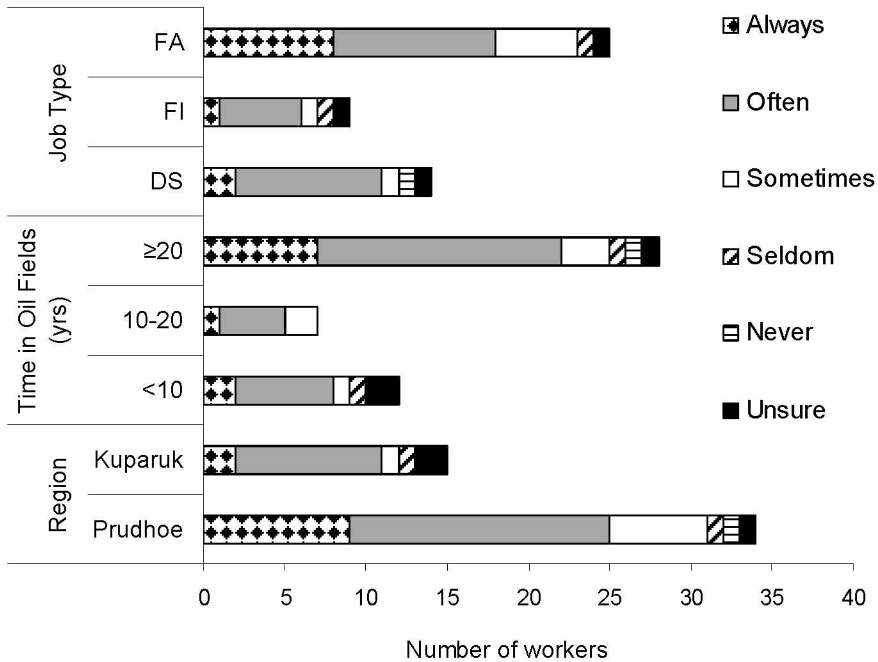


Figure 2.3. Oil field workers' observations of raven occurrence at processing facilities during winter in Kuparuk and Prudhoe Bay oil fields, Alaska, based on questionnaires completed in 2006. Responses were stratified by job type (FA- Facility Operators, DS-Drill Site Operators, and FI- Field Operators), length of time working in the oil fields, and oil field.

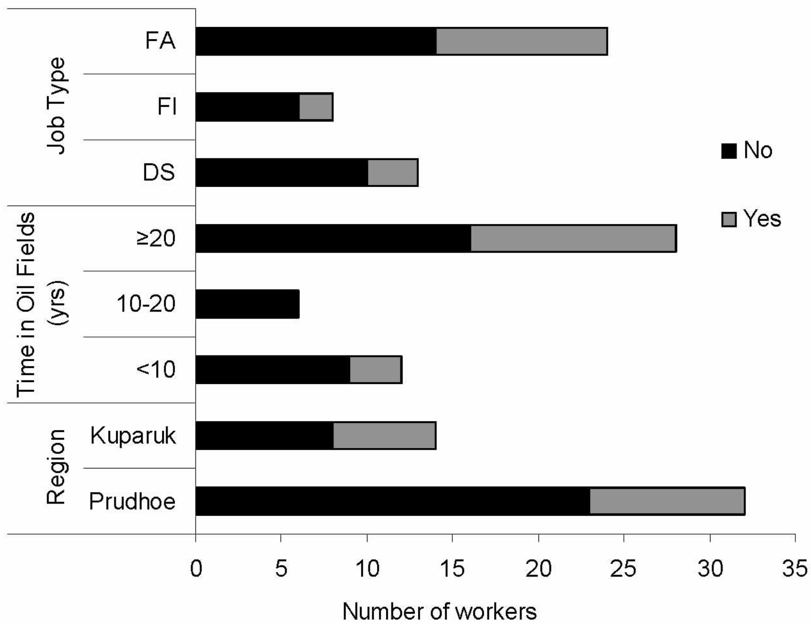


Figure 2.4. Oil field workers' observations of ravens caching food in Kuparuk and Prudhoe Bay oil fields, Alaska based on questionnaires completed in 2006. Responses were stratified by job type (FA- Facility Operators, DS- Drill Site Operators, and FI- Field Operators), length of time working in the oil fields, and oil field.

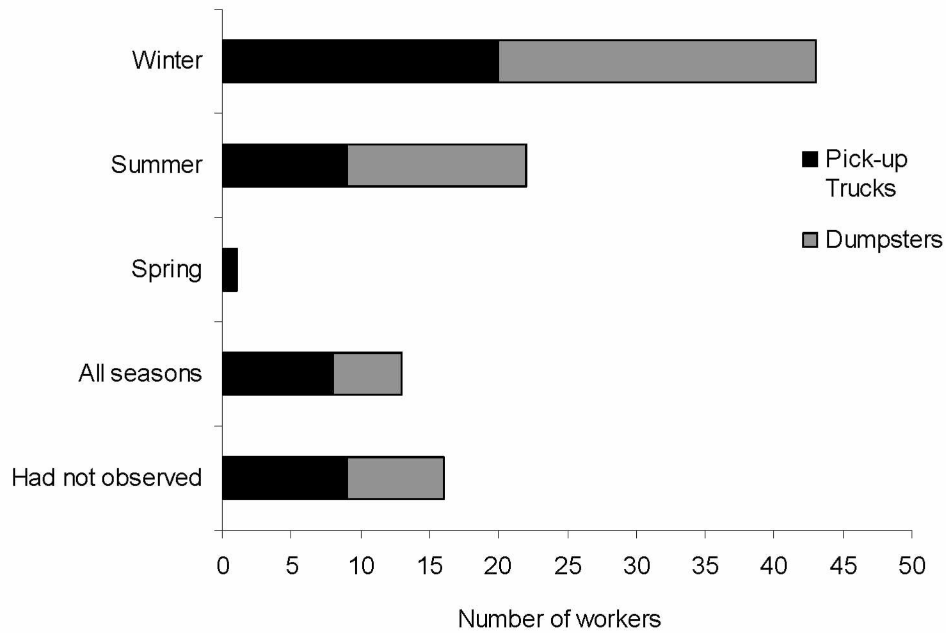


Figure 2.5. Oil field workers' perspectives of the season they most commonly observed ravens at dumpsters and pick-up trucks in the Kuparuk and Prudhoe Bay oil fields, Alaska, based on questionnaires completed in 2006.

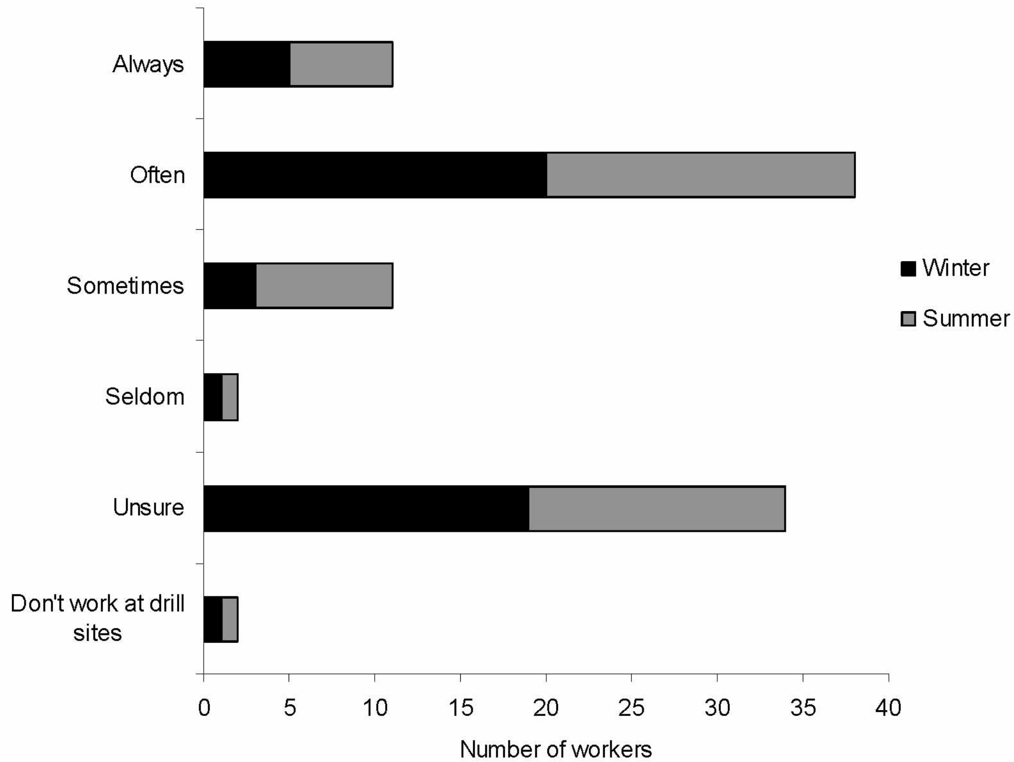


Figure 2.6. Oil field workers' perspectives of the frequency they observed ravens at drill sites when human activity was heightened (e.g. drilling rig activity), during winter and summer, in the Kuparuk and Prudhoe Bay oil fields, Alaska. Perspectives were based on questionnaires completed in 2006

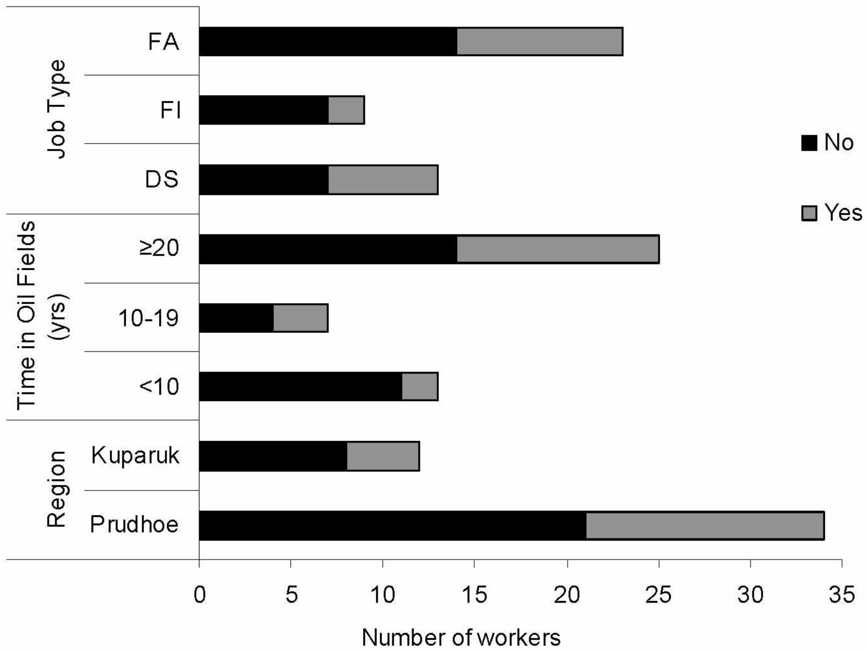


Figure 2.7. Oil field workers' confirmation of having observed ravens with eggs of other birds in Kuparuk and Prudhoe Bay oil fields, Alaska, based on questionnaires completed in 2006. Responses were stratified by job type (FA- Facility Operators, DS- Drill Site Operators, and FI- Field Operators), length of time working in the oil fields, and oil field.

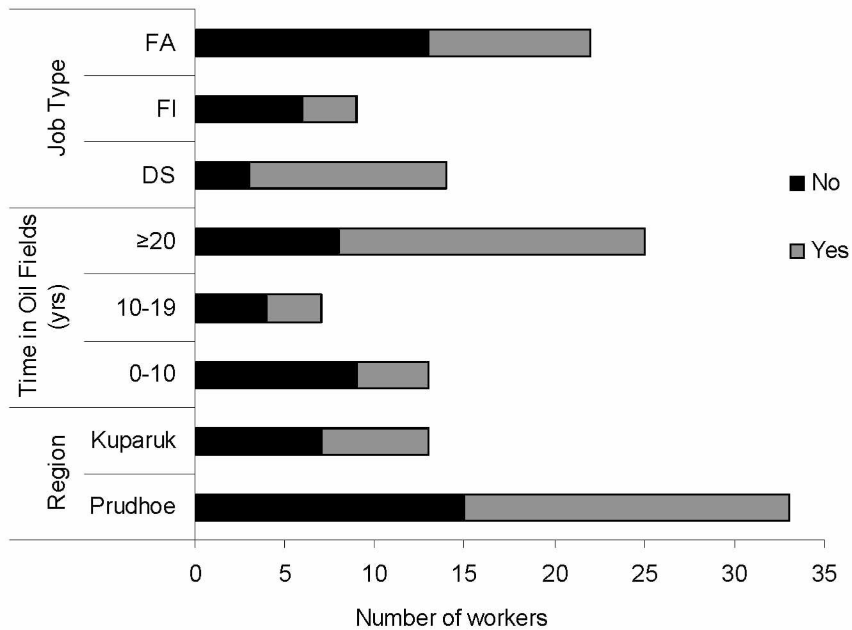


Figure 2.8. Oil field workers' confirmation of having observed ravens with bird or rodent prey in the Kuparuk and Prudhoe Bay oil fields, Alaska, based on questionnaires completed in 2006. Responses were stratified by job type (FA- Facility Operators, DS-Drill Site Operators, and FI- Field Operators), length of time working in the oil fields, and oil field.

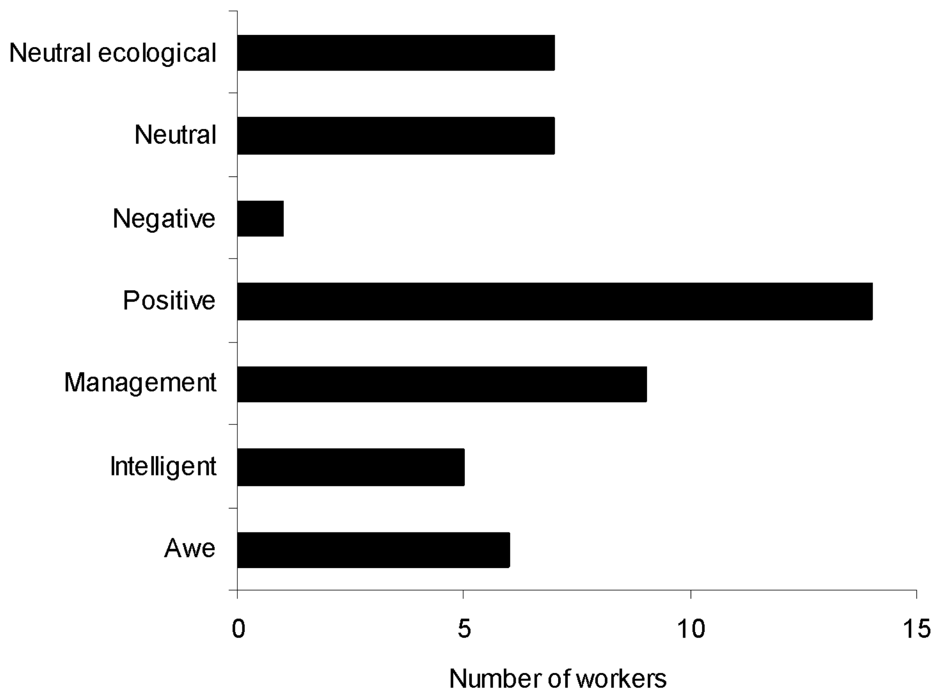
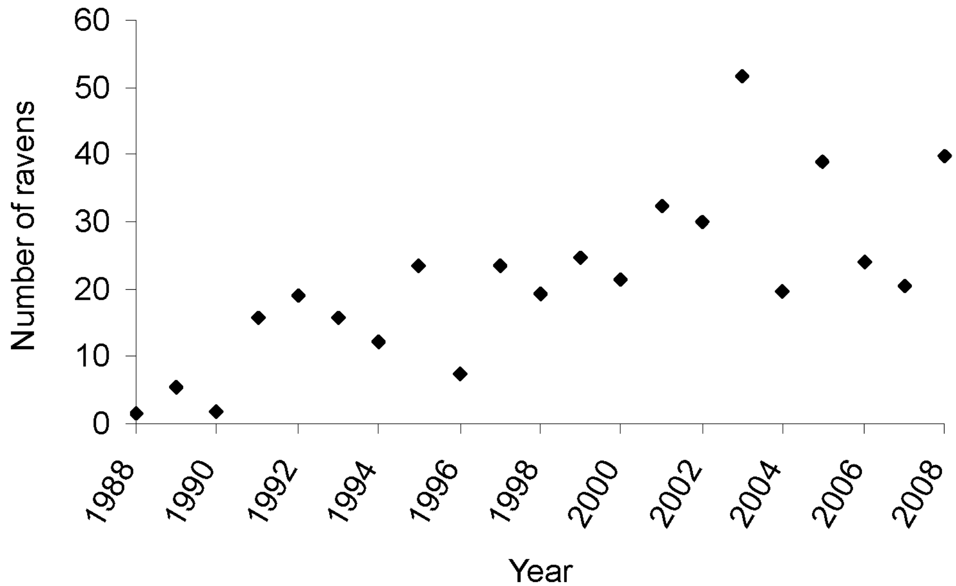
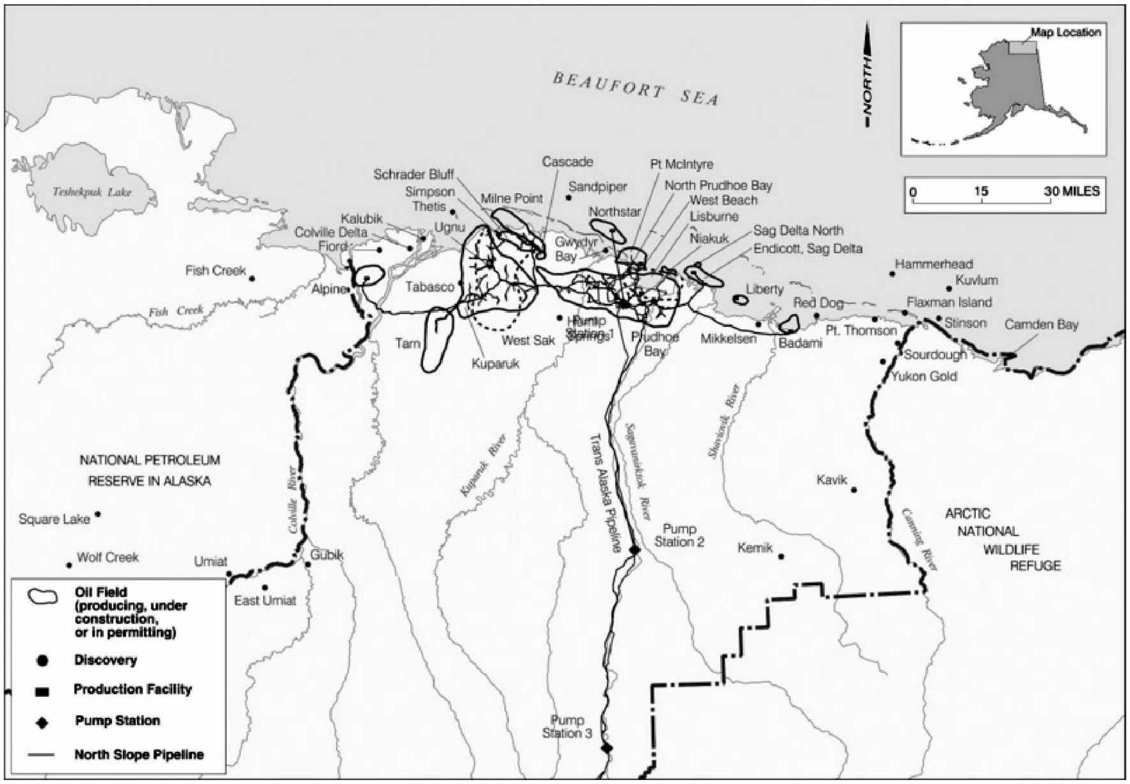


Figure 2.9. Oil field workers' personal feelings and characterizations of ravens in the Kuparuk and Prudhoe Bay oil fields, Alaska, based on questionnaires completed in 2006. The 'Neutral ecological' category represents neutral attitudes towards ravens with references made to their ecological role in the environment. The category 'Management' includes statements made about ravens colonizing the oil fields and acknowledging the linkages between oil field activities and increased raven numbers in the oil fields.

Appendix 2.1. Christmas Bird Counts of ravens at Prudhoe Bay, Alaska from 1988-2008, (National Audubon Society, 2009). Counts are standardized by number of birds counted per party hour to reflect effort expended searching for ravens.



Appendix 2.2. Location of Alaska's North Slope oil fields (Source: Trans-Alaska Pipeline System Renewal EIS, http://tapseis.anl.gov).



Appendix 2.5. Focus group script used for focus group and individual interviews with oil field workers in 2005, in Kuparuk and Prudhoe Bay oil fields, Alaska.

Focus Group Script

Introduction

I will begin each meeting with an explanation of the study and why the participants have been invited to participate. I will explain to them how the meeting will be managed. I will then distribute and explain the biographical questionnaire and consent forms. While they are filling out the forms, I will finish last minute preparations of electronic recording equipment and visual aids. After they have completed the forms and questions regarding these forms we will begin the meeting.

First, I will distribute maps of the field to every participant to reference. I will use a flip chart to document discussion points. Questions will be displayed on the dry erase board in the meeting room. Audio and video recorders will be running for the duration of the meeting.

Beginning of Discussion

Before I proceed with interview questions, I will take questions regarding the meeting agenda and process.

List of Questions

I will use the following list of questions to guide the focus group and cover topic areas.

Change and Seasonality

- When did you first notice ravens here?
- Are you seeing more ravens now then in the past?
- Where and when do you see ravens?
- Has the number of ravens changed between now and the first time you noticed them?
- Do you see more in the summer? The winter?
- Where do you see them in the winter?
- Are there areas you think are more important to ravens than others? What are they?

Appendix 2.5. (cont.)

Breeding Activities

- Where do you see ravens nesting?
- When did you notice the first nest at this facility?
- Did you also see any nests at drill sites during this time?
- Have ravens nested here every year?
- Were they reusing the same nest or building new ones?
- Where was the nest(s) located?
- Were there any years they nested but didn't have young?
- During the summer where did you most commonly see them feeding?
- Where do they get nest materials?
- What types of materials?
- Where do you see the adults flying to and away from the facility?
- What types of activities have you seen them doing?

Infrastructure use

- Where have you seen ravens at this facility?
- What parts of this facility do you frequently see them?
- Why do you think these are used more than others?

Food

- Where do you see ravens getting food in the winter? Summer?
- Do you see ravens take eggs or chicks from other birds' nests? What did the eggs/chicks look like?

Management issues

- Do ravens interfere with production activities?
- (If yes) What are some of the ways?
- Do you think it's possible to keep them from establishing nests at this facility?
- Have you tried to deter them from nesting here?
- If yes, what was their response?
- Do you think that more ravens will continue to breed on unoccupied structures if we don't deter them?
- How do others here talk about ravens?

Meeting Summary

To conclude the meeting I will clarify the key points brought up in the discussion. I will devote the last 10 minutes to respond to questions about the process and contact information.

Appendix 2.6. The biographical information request distributed to interview participants during focus group and individual interviews in 2005 in the Kuparuk and Prudhoe Bay oil fields, Alaska.

Research Participant Biographical Sketch

Code ________________________

Facility ________________ Date ________________

Current Position Title

____

Length of time working at this facility/or affiliated pads

____

Length of time working in the North Slope oil fields

____

Other locations you have worked at in the North Slope oil fields

____

Other positions you have held during time spent working on the slope

____

Appendix 2.7. Questionnaire survey instrument distributed to oil fields workers in 2006, in the Kuparuk and Prudhoe Bay oil fields, Alaska.

2006 North Slope Oil Fields Raven Survey

Your Background

1. What is your position title?

2. How many years have you worked in the oil fields and what year did you start?

3. Please circle the fields where you have worked in the past, place a check in Current Location indicating where you work now, and list number of months or years you worked in the other locations:

	Current Location (place √ and list facility/area)	**Number of months or years**
Prudhoe		
Kuparuk		
Alpine		
Milne Pt		
Pt. Thompson		
Badami		
Endicott		
Other (please list)		

Raven Population

1. **Is the number of ravens in the oil fields** (please circle one of the following):
increasing   decreasing   staying the same   unsure

If increasing, what magnitude of increase would you say has occurred in the population from the time you started working in the oil fields? *Please circle one of the following:*
a. small increase (1% to 25 %)
b. significant increase (26%-50%)
c. major increase (50% or greater)

2. Are there more ravens in the oil fields in the summer (May – August) or winter (September – April)? *Please circle one of the following:*
a. summer
b. winter
c. unsure

Appendix 2.7. (cont.)

	Raven 1	Raven 2	Raven 3
• **Tag Color**			
• **Tag Code**			
• **Locations (as specific as possible)**			
• **When you saw the bird (year, season, date if possible)**			
• **Number of times you have seen this individual**			

Foraging and movement patterns

1. When are you more likely to see ravens investigating the back of pick-up trucks?
Please circle one of the following:
winter summer have not observed this

2. When are you more likely to see ravens perched on or near dumpsters?
Please circle one of the following:
winter summer have not observed this

3. Have you seen ravens cache food on facilities? *Please circle one: Y or N*
If yes, where have you observed caches?
Please list:
1. ______________________________
2. ______________________________
3. ______________________________

4. During summer (May – August) do you see ravens eating or flying with eggs (of other birds)?
Please circle one: Y or N

5. During summer (May – August) do you see ravens eating or flying with small animals (birds or rodents)?
Please circle one: Y or N

Appendix 2.7. (cont.)

Nesting

1. Please list facilities and/or field locations where you have seen raven nests.

____
____
____
____

2. When do you recall first seeing a raven nest on a facility?

Year: ______________________________________
Location: ______________________________________

3. Do nesting ravens interfere with your work activities?
If yes, please list 3 ways they do:
1. ______________________________________
2. ______________________________________
3. ______________________________________

More on ravens

1. Have you had personal encounters with ravens in the oil fields?
Please circle one: Y or N
Please describe the encounter:

2. Describe your general thoughts on ravens in the oil fields.

CHAPTER 3. INDUSTRIAL NEST ECOLOGY: COMMON RAVENS IN ALASKA'S NORTH SLOPE OIL FIELDS[1].

ABSTRACT

Common ravens (*Corvus corax*) that nest on human structures in the treeless landscape of the Kuparuk and Prudhoe Bay oil fields on Alaska's North Slope are believed to present a predation risk to tundra-nesting birds in this area. In order to understand how anthropogenic subsidies in the oil fields affect this population, I examined the influence of types of structures and food subsidies on raven nest site use and productivity in Kuparuk and Prudhoe Bay. I documented raven nest locations from 2004 - 2007 and monitored productivity from 2004 - 2006. I used a regression tree classification modeling approach to predict nest site use and productivity based on the type of structure on which ravens placed nests and proximity of nests to food subsidies such as landfills, oil field worker camps, and drilling rig activity. The oil fields hosted 18 - 25 breeding pairs each year that nested on processing facilities, drill sites, bridges, inactive drill rigs, and radar towers. Nests were closer together (0.07 nests/km^2) and more numerous in the eastern region (Prudhoe Bay) where building density was highest and a landfill was located, but the most important predictors of nest site use were proximity to nearest raven nest and the type of structure used for nesting;

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[1] Prepared for submission to Arctic as Backensto, S and A. Powell. Industrial Nest Ecology: Common Ravens (*Corvus corax*) in Alaska's North Slope Oil Fields.

processing facilities, bridges, inactive drill rigs, and radar towers were used more than drill sites. Most nests (70%, n = 64) were successful at fledging young; ravens fledged 3.0 ± 2.0 young/nest, which was similar to other populations breeding on human structures or elsewhere in the Arctic. Productivity for this population was linked to nest initiation date and to a lesser extent individual nest site. Nests on drill sites were the least successful at fledging young and were initiated on average 13.5 ± 5.4 later than those on processing facilities, and 7.1 ± 6.5 days later than nests on bridges, inactive drilling rigs, and radar towers. I found no evidence to suggest that anthropogenic food subsidies affected productivity, and raven use of the landfill was low during most of the breeding season. This population appears to be limited by suitable nest sites. I suggest that drill sites are of marginal quality because they provide few options to place or protect a nest and may be used by younger, less experienced individuals. Older and experienced ravens may choose to nest on processing facilities, bridges, radar towers, and inactive drill rigs because they have more opportunities for nest placement and warmer microclimates. My interpretations are confounded by spatial correlations among variables in the study area, and further research will be necessary to identify how age and experience of individuals affect nest site use and productivity of this population and how food (anthropogenic and natural) availability affects production of offspring.

Key words: ravens, oil fields, nest site use, anthropogenic subsides

INTRODUCTION

Humans influence common raven (*Corvus corax*) populations by providing supplemental food sources and structures for roosting and nesting (Boarman and Heinrich, 1999; Preston, 2005; Boarman et al., 2006). Anthropogenic food subsidies influence distribution of raven nests and positively affect raven productivity and juvenile survival and movements (Webb et al., 2004; Marzluff and Neatherlin, 2006; White, 2006; Kristan and Boarman, 2007; Webb et al., 2009). Ravens nest on human structures throughout their range (Tryjanowski et al., 2004; Ratcliffe, 1997; Kristan and Boarman, 2007) and in California, Oregon, and Idaho frequently use power poles and power transmission towers as nest sites (Knight and Kawashima, 1993; Steenhof et al., 1993). These types of structures are believed to benefit raven nestlings more than natural substrates in hot, arid environments by providing cooler nest microclimates through shading and increased wind exposure; overheating is a source of mortality for Chihuahuan raven (*C. cryptoleucus*) nestlings and juvenile common ravens in the Mojave Desert (Webb et al., 2004; Burton and Mueller, 2006).

On the coastal plain of Alaska's North Slope, human structures associated with radar towers at military installations and the Kuparuk and Prudhoe Bay oil fields have provided nesting habitat for ravens in a treeless, low relief area. Prior to large-scale industrial development, it is believed ravens nested primarily on cliffs along river systems in the foothills of the Brooks Range, approximately 150 km south of the oil fields (White and Cade, 1971). Besides buildings in human settlements, the only other structures on the coastal plain before the oil fields were 17 Radar System (ARS) sites established by U.S. Air Force, 1955-1957, at approximately 80 km intervals along the coastline (Appendix 3.1; Lackenbauer et al., 2005; S. Fritz, UAF pers. comm.). Construction of the Prudhoe Bay oil field began with an airstrip and camp facility in 1968; roads, oil processing facilities, and drill sites were established by 1970. In 1978 a permanent landfill was established in Prudhoe Bay (J. Singleton, Service Area 10 North Slope Borough, pers. comm.), and construction of the Kuparuk oil field began. By 1983 roughly half of the structures that currently exist in the Kuparuk and Prudhoe Bay oil fields had been built. The next significant period of growth in these oil fields occurred in the late 1980s through the early 1990s (National Research Council, 2003). Smaller satellite oil fields (Alpine and Badami) built in the mid-late 1990s are located roughly 30 km to the west and east of Kuparuk and Prudhoe Bay (Appendix 3.2; National Research Council, 2003).

Introduction of these human-made structures has allowed ravens to expand their breeding range into previously unoccupied areas of Alaska's coastal plain, fueling concern over their potential impact on tundra-nesting waterfowl and shorebirds (Day, 1998; USFWS, 2003). Alaska's coastal plain is an important area for breeding migratory waterfowl and shorebirds, some of which are species of special conservation concern, such as yellow-billed loons (*Gavia adamsii*) and Steller's (*Polysticta stelleri*) and spectacled eiders (*Somateria fisheri*; Sea Duck Joint Venture Continental Technical Team, 2003; Earnst, 2004). Ravens are known nest predators throughout their range (Boarman and Heinrich, 1999), and increased numbers of breeding ravens are often associated with higher predation on local prey species, especially near raven nest sites and large food bonanzas like landfills (Kristan and Boarman, 2003). Because the oil fields contain few natural nesting structures for ravens, it is assumed that ravens formerly occurred in low numbers and exerted little pressure on tundra-nesting birds.

Little is known about the nesting biology and nest site selection of ravens in the Arctic (White and Cade, 1971; Skarphedinsson et al., 1990) and a population totally dependent on human structures for nest substrates has not been documented to the best of my knowledge. Oil field structures on Alaska's coastal plain may yield additional benefits to ravens by providing warm locations for nests. In interior Alaska, tolerance to cold stress by adult ravens during winter has been attributed to two strategies: constant daily metabolism to maintain high heat production (Schwan and Williams, 1978) and nocturnal hypothermia (Clarkson, 1996). Warmer nest sites in the Arctic could considerably reduce energetic requirements of incubating and brooding adults by altering the degree to which these thermoregulatory strategies are employed. Metabolic rate can be significantly reduced by a simple change in a bird's microclimate (Wolf and Walsberg, 1996); female common eiders (*Somateria mollissima*) that nested in sheltered environments were in better body condition than females that nested in more exposed areas (Fast et al., 2007). Warmer nest sites in the oil field might also provide similar benefits to raven nestlings. Hyperthermia of raven nestlings observed in hot arid environments (Webb et al., 2004; Burton and Mueller, 2006) is probably not a major cause of nestling mortality in the oil fields, but hypothermia may be, especially early in the nestling period when temperatures can still be as low as -37 ^{o}C (National Climate Data Center et al., 2009). Experimental research showed that warmer nest sites positively influenced growth rates and survival of tree swallow (*Tachycineta bicolor*) nestlings in British Columbia, Canada (Dawson et al., 2005).

In addition to structures, the oil fields may also subsidize breeding ravens by providing anthropogenic food resources. Food subsidies are important supplemental food sources to breeding ravens throughout their range (Kristan et al., 2004; Marzluff and Neatherlin, 2006; White, 2006; Kristan and Boarman, 2007). In the oil fields, a landfill and available food associated with human activity may be important for breeding ravens because the landscape is snow-covered for most of the year and natural food resources are presumably low.

I assessed the breeding population of ravens in the Kuparuk and Prudhoe Bay oil fields and investigated the importance of structures and anthropogenic food sources for nest site use and productivity. The main objectives of this study were to: 1) document and describe nest locations and characteristics, 2) describe ravens' use of the local landfill during the breeding season, 3) relate nest site use to type of structure (nest site) and proximity to anthropogenic food subsidies, 4) document and describe raven breeding biology, and 5) relate productivity of this population to type of nest site and proximity to anthropogenic food sources. For nest site use (objective 3), I hypothesized that large, complex structures such as processing facilities, despite being less abundant, would be used more frequently than more abundant, smaller, and less complex structures. Processing facilities are complex structures that produce a large amount of heat (Backensto and Kofinas, 2010), and these two qualities should offer more options for a protected, warm nest than smaller, less complex structures producing less heat such as drill sites, or complex structures with no heat such as bridges, ARS towers, and inactive drill rigs. Additionally, some processing facilities were known to serve as nest sites for more than 20 years (Backensto and Kofinas, 2010). I also hypothesized those structures closer to anthropogenic food sources would be used as nest sites more frequently than other structures because ravens would have better access to supplemental food when natural food sources were limited. For productivity (objective 5), I expected that nests at processing facilities would be more productive than nests at drill sites, bridges, ARS towers, and inactive rigs because I presumed warmer nest microclimates at processing facilities would benefit nestlings. I also predicted that nests near anthropogenic food sources would be more productive because adults nesting near these subsidies would have access to supplemental food for provisioning young.

Future management of ravens in the oil fields may require a reduction in raven nesting activity to slow population growth and reduce their impact as nest predators of tundra-nesting birds; therefore evaluating use of structures for nesting in the oil fields will be important to the success of these efforts. Likewise, investigating factors that influence reproductive performance of this population can also help managers identify which structures in the oil fields are important for recruitment.

METHODS

Study Area

The coastal plain is the lowest physiographic region of the North Slope; the oil fields are characterized by extensive wetlands and tundra and are flanked by the Colville and Sagavanirktok rivers (Cabot, 1947; National Research Council, 2003). Air temperature ranges between -50° C - 25° C, annual precipitation is 13-18 cm, and the ground is snow-covered for more than half of the year (Truett, 2000; National Research Council, 2003).

This study included the two largest producing oil fields on Alaska's North Slope: Kuparuk (103,396 ha, operated primarily by ConocoPhillips Alaska Inc. and BP Exploration (Alaska) Inc.) and Prudhoe Bay (122,595 ha, operated by BP Exploration (Alaska) Inc.). I refer to both Kuparuk and Prudhoe Bay as one oil field, which I divided into western and eastern regions (Fig. 3.1) because the densities of structures varied between them; infrastructure was denser in the eastern region (Appendix 3.3). The western region included Kuparuk and Milne Pt. structures west of the Milne Pt. Road intersection with Spine Road. The eastern region included all remaining structures, including those in Deadhorse (a 400 ha service area with warehouse buildings and camp facilities, often referred to as an industrial town). The oil fields contained a mosaic of buildings and pipelines connected by a gravel road network across the tundra. Although smaller satellite oil fields occurred to the east and west of the study area, I confined this study to the road system because of logistical constraints, with the exception of one offshore facility 6 km north of the eastern region.

Two main types of structures associated with oil production activities characterized the oil field: processing facilities and drill sites (Fig. 3.2). Processing facilities were a collection of large modular buildings 40 - 60 m tall, had numerous protruding features on their exterior, and were not abundant (n = 19). Drill sites, in contrast, were smaller modular buildings (5 - 15 m tall) connected to several smaller well houses on the same gravel pad, had relatively fewer exterior features, and were more abundant (n = 123) than processing facilities. Because of engineering advances drill sites varied in shape and size across the oil field; drill sites were older and generally larger in the eastern region.

Other types of structures (herein referred to as “other structures”) in the oil field were variable in height (5 - 60 m, Fig. 3.2) and included bridges, ARS towers, inactive drilling rigs (herein referred to as inactive rigs), and warehouses. Bridges, ARS towers, and inactive rigs were least abundant (n = 13) relative to warehouses (n = 59). Power poles and vertical support members (VSM) for pipelines were ubiquitous throughout the study area, but I did not include them in the analyses, because neither had horizontal cross beams on which to support a nest, and oil field workers indicated no one had ever seen a nest on either type of structure.

Anthropogenic food sources occurred as large, available point subsidies (landfills) and smaller, less available, ephemeral subsidies associated with human activities. There were two landfills in and near the oil field: a Class 1 landfill (10 ha) in Prudhoe Bay (in the eastern region) that accepted 20 tons or more of municipal solid waste and other solid wastes daily for incineration or disposal, and a Class 3 landfill (8 ha) in the village of Nuiqsut (50 km southwest of the western region) that accepted less than five tons daily of municipal solid waste for disposal, or one ton of ash, incinerated from municipal waste daily (Alaska Department of Environmental Conservation, 2009). Food wastes at the Prudhoe Bay Landfill were covered daily by 15 cm of gravel whereas at the Nuiqsut landfill they were incinerated regularly, weather permitting (Department of Public Works, North Slope Borough, pers. comm.).

I considered human activity as an ephemeral subsidy because the amount of food wastes it provided was substantially less compared to landfills. For example, food unintentionally left in the bed of pick-up trucks or discarded on the ground near a covered food dumpster was associated with human activity. Human activity was difficult to quantify, but I observed that its levels varied spatially and temporally throughout the study area. During times of peak activity, roughly 3000 people lived and worked in the oil field on a daily basis and resided in 13 main camps and three satellite camps (two on the road system and one offshore) that were part of remote processing facilities (ConocoPhillips Alaska Inc., Department of Health Safety and the Environment, pers. comm.). Human activity was generally high at camps, and each camp had one covered food dumpster. The oil companies managed food wastes to reduce accessibility to wildlife; starting in the mid-1990s food dumpsters were outfitted with lids and wastes were transferred to and buried at the Prudhoe Bay Landfill (R. Shideler, Alaska Dept. of Fish and Game, pers. comm.). I also considered drilling rig activity (herein referred to as rig activity) as an ephemeral subsidy because this activity temporarily increased the number of workers at a drill site and was accompanied by a temporary, covered, food dumpster. Workers observed ravens at locations where drilling rig activity occurred during the winter (Backensto and Kofinas, 2010).

Nest Site Use

I searched for raven nests from late April through early June 2004 - 2006 and until 7 May in 2007 by driving all roads throughout the study area and visually inspecting all structures for signs of raven nesting activity on the road system. Raven nests were fairly conspicuous and easy to locate using this method; however, I also discussed the presence of ravens with facility personnel at processing facilities and drill sites across the oil field. I surveyed approximately 80% of the oil field in 2007 due to inclement weather and road restrictions, but I talked with personnel working at inaccessible sites and other researchers that completed a similar survey later in the summer of 2007 (A. Stickney, ABR Inc., pers. comm.); thus I am confident that I documented most nests initiated in that year. I recorded the type of structure nests were placed on as a processing facility, drill site, or other structure. Locations of nests were mapped in Arcview 3.3 GIS (Hooge and Eichenlaub, 2000) using GIS layers provided by BP Exploration, (Alaska) Inc.

I present the number of nests used in each year, and the proportion of nests used among types of structure (processing facilities, drill sites, and other structures; Table 3.1) and over multiple years. Two nests placed on tanks adjacent to drill site modules were categorized as drill site nests. Fidelity to structures by individual ravens was expressed as the number of known individuals (marked for another study) that returned to their nest sites in subsequent years. I described the distance of nests to nearest neighbor and food subsidies (Table 3.1) for all nests found in 2004 - 2007, among types of structures and by region. I used ArcView GIS 3.3 (Hooge and Eichenlaub, 2000) to calculate nest density for each region and to measure distances variables.

Nest Characteristics

For each nest found, I recorded nesting materials, height, substrates, general orientation, and exposure (estimated as percentage of cover from above and along the sides of the nest). I used binoculars to inspect the exterior portion of the nest and to determine the types of materials ravens used. Substrate type was described in two ways: type of structure and whether or not the substrate was heated, which was confirmed by oil field workers at the nest site. Nest characteristics, except materials, were reported in proportion to type of structure or as means ± s.d. unless otherwise noted. Cover was described as percentages of cover above and to the sides. I used all nest attempts documented in 2004 - 2007 for comparisons of nest characteristics, but omitted one nest found in 2007 by other researchers for which I did not have the necessary information. I omitted 38% (n = 89) of nests that were used in subsequent years for this summary because the actual nest had not changed location on the structure.

Use of anthropogenic subsidies

I recorded the number of ravens at the landfill in Prudhoe Bay to estimate the use of this anthropogenic food source during the breeding season. I visited the landfill approximately 1 - 3 times per week from late April through August each year (19 visits in 2004, 51 in 2005, 50 in 2006, and 3 in 2007) to count ravens and identify known individuals (marked for another study). Counts consisted of driving into the landfill and estimating the total number of ravens for a period of 15 minutes. I summarized landfill use by reporting maximum number of adults and juveniles seen each month.

Analysis of Factors Affecting Nest Site Use

I used a regression tree classification model (TreeNet; Salford Systems Inc., 2003) to explore and assess the relative importance of structure type and food subsidies in predicting nest site use. The use of this procedure resembles data mining, and is increasingly applied in the field of ecology because it optimizes predictive performance of models to identify non-linear relationships and high-order interactions that other generalized linear models and maximum likelihood approaches may fail to identify (Hastie et al., 2001; Craig and Huettmann, 2008; Elith et al., 2008). I used a two-fold process. First I built decision trees based on the data set using an algorithm that split the data set into binary groups at points that minimized prediction errors. Decision trees were then improved using a stage-wise procedure (boosting) and cross validation techniques on two random subsets of the data. The first subset (*learn data*) was sampled randomly to build decision trees, while the second subset (*test data*) represented the remainder of the data not chosen and used to test the predictive accuracy of trees through cross validation for a 'boosted performance'. Variable importance was estimated through permutation procedures assessing reduction in model accuracy, summarizing how often specific variables were used in this boosting process (Friedman, 2002; Elith et al., 2008).

I used six explanatory variables for this analysis, five of which represented anthropogenic factors for predicting nest site use (Table 3.1). To address my hypothesis that processing facilities were important predictors of nest site use, I classified type of structure (*Site Type*) into four levels, each representing a degree of structural complexity and heat production (Table 3.1). I used the distance of nest sites to three types of food subsidies (*Camp, Landfill*, drilling rig activity in *February* and *March*; Table 3.1) to determine whether anthropogenic food sources were important predictors. I also included distance of sites to nearest nesting raven pair (*Neighbor*) because ravens are known to be territorial (Table 3.1). All distance variables were derived in ArcView GIS 3.3 (Hooge and Eichenlaub, 2000). I used all known nest attempts from 2004 - 2007 as "used" sites (n = 41). To avoid psuedoreplication I averaged all measurements for each distance parameter for those sites used repeatedly during the study (n = 24).

I selected all unused sites (n = 173) from GIS layers of the entire oil field provided by BP Exploration (Alaska) Inc. Unused sites included processing facilities, drill sites, camps, and other structures deemed suitable for nesting (bridges and warehouses) based on nest use patterns observed during this study and by oil field workers (Backensto and Kofinas, 2010). Although processing facilities were made up of a complex of multiple buildings, I considered them as one site because I observed that only one raven pair nested at these facilities each year. This was also confirmed by oil field workers during informal conversations. Drill sites, also a set of multiple structures, were treated in the same manner for similar reasons. GIS layers for other structures were represented by a polygon shape that often included more than one building, most of which were located in Deadhorse (eastern region). Where possible, I treated each building as a separate site. I had an on-the-ground working knowledge of these structures and feel that this GIS selection accurately represented most of the buildings in Deadhorse. Because most of the other structures in this analysis were made up of warehouse buildings, I further subdivided other structures into two categories: *Other* and *Warehouse* (Table 3.1).

To interpret model performance I used the Area Under the Curve (AUC) for receiver operating characteristic curves (Mason and Graham, 2002) and variable importance rankings (Friedman, 2002) to determine which variables were the most influential predictors of site use. I report AUC for the regression tree model built on *learn* data, and for the evaluation of that model using *test* data. I also present variable importance rankings which represent the relative influence of the predictor variables on the response variable; rankings were standardized with the most important variable ranked at 100%. I also present partial dependence plots for the most important variables that visually represent the individual relationship between a predictor variable and the response variable (in this case the index of site use) after averaging out the effects of all other predictor variables (Friedman, 2002; Elith et al., 2008).

Breeding Biology

I attempted to monitor nests every 5 - 7 days throughout the breeding season until they either failed or fledged young in all years except 2007. When possible, I checked for presence of eggs or chicks using a mirror and extension pole; however, because of safety concerns and company policies, this was not often achieved. Therefore, I assumed adults on nests were incubating eggs until I observed chick-feeding behavior. On some occasions, I documented observations made by oil field personnel about the stage of specific nests. I defined a nest attempt as those nests where I witnessed either nest building or incubating behavior.

I described phenology, success, and productivity for nests found in 2004 - 2006. Because I did not always know initiation or hatch dates, I back-dated from known events such as fledging to estimate dates for these events. I used a 23-day interval as the average incubation period (Stiehl, 1985; Boarman and Heinrich, 1999) and a 41-day interval from hatch until fledging based on my observations. I defined successful nests as the proportion of nest attempts that produced at least one fledgling. Productivity was estimated in two ways: the number of fledglings produced per nest attempt and the number of fledglings produced per successful nest. Means are presented ± standard deviation for regions, types of structure, and year. One nest was removed during nest-building in 2004 (both oil companies removed raven nests prior to egg-laying if they were considered to impede production activities), and another nest was abandoned shortly after I captured one of the adults in 2005. In addition, I could not estimate success and productivity for six other nest attempts. Five nests could not be accessed during fledging and one was found late in the breeding season- I was unable to determine its outcome. Four of these six nests were on processing facilities; therefore, reproductive success for these site types may be biased low.

Analysis of Factors Affecting Productivity

I used a regression tree classification approach to investigate the hypotheses that structure type and food subsidies influence productivity. I used 13 variables for this analysis, of which eight were factors hypothesized to be important for explaining productivity. The other five variables were considered factors that may have affected productivity but were not directly related to my hypotheses. To determine whether nests located on processing facilities had higher productivity than drill sites and other structures, nest sites were classified in the same way used in the nest site use analysis (*Site type*, Table 3.1), but I also included nest characteristics (*Aspect, Height, Heated Substrate, Above and Side Cover*) to isolate their individual importance from the general classification of structures. I used *Camp* and *Landfill* (Table 3.1) to determine if these food subsidies were important predictors of productivity. I excluded rig activity (*February, March*) because as a food subsidy its effect on productivity should be minimal during the early stages of nesting when eggs had not yet hatched. *Neighbor* was included to account for an effect of territorial behavior (Table 3.1). I added *Region* because productivity was slightly lower in the western region. *Nest initiation date* was included because early nests are more productive than late nests in other raven populations (Dunk et al., 1997; Kristan and Boarman, 2007), and *Year* was included to account for annual variation in productivity. I also added *Nest I.D.* because 58% of nest sites were used more than once during the study and I used only those nests for which I was able to estimate productivity (2004-2006, n = 56) in this analysis.

Given the limited sample size and the number of parameters in the model, I binned productivity estimates into high (4-7), low (1-3), and none (0) categories to represent the number of fledglings for each observation. I based this decision on the range of number of fledglings per nest I observed in the oil field and fledgling averages elsewhere in North America, and thus I feel the these categories reflect the range of fledglings produced per nest in my study area (Dunk et al., 1997; Boarman and Heinrich, 1999; Kristan and Boarman, 2007). I report AUC for the regression tree model built on learn data and evaluated on test data for each level of productivity (high, low, none). I also report variable importance rankings.

RESULTS

Nest Site Use

I documented a total of 89 raven nests from 2004 - 2007: 18 in 2004, 21 in 2005, 25 in 2006, and 25 in 2007 (Fig. 3.1). Nests were built primarily on processing facilities (n = 40), drill sites (n = 32), and to a lesser extent on other structures (n = 17). A total of 41 individual sites were used for nesting during this study. A proportion of these sites were reused in subsequent years: 22% were used in all four years, 15% in three years, and 22% in two years. Of the nine nest sites used in all four years, seven were on processing facilities. A processing facility located 6 km offshore supported a raven nest for three consecutive years. Four out of nine marked adults re-used their nest sites in subsequent years.

Nest density was higher each year in the eastern (0.07 pairs/km^2) than western region (0.01 pairs/km^2, Fig. 3.1), corresponding to higher densities of structures in Prudhoe. Likewise, nests in the eastern region were closer to their neighbors and to all food subsidies (Table 3.2). Nests at processing facilities were closer to camps and rig activity in February, but overall differences between types of nests sites and distance to food subsidies were small (Table 3.2).

Nest Characteristics

I observed that ravens in the oil fields used primarily industrial materials to build nests. These included survey markers, plastic, wire, metal objects, and driftwood; but oil field workers provided an even more detailed list (Backensto and Kofinas, 2010). Raven nests were placed primarily on pipes and structural support beams of buildings, bridges, and large tanks (Table 3.3). Nests placed on structural beams were most common at processing facilities and other structures, nests on pipes were found only at processing facilities and drill sites, and nests on exhaust vents were found only at drill sites. Nests were not always placed on the tallest portions of structures and were highest at processing facilities and other structures (Table 3.3).

Half of all nests faced south, most of which were on drill sites (Table 3.3). Less than half of the nests at processing facilities and drill sites were on heated substrates, and no nests were on heated substrates at other structures. Overall, nests were most exposed at drill sites (Table 3.3).

Landfill Use

Ravens were most abundant at the Prudhoe Landfill in April and May and least abundant in June and July (Fig. 3.3). In general, use of the landfill by ravens was minimal during brooding, chick rearing, and fledging periods; the maximum number observed in the landfill from June through August was fewer than 15 birds. Marked juveniles were observed using the landfill in all months (Fig. 3.3). Two marked adults that nested at two different nests < 5 km from the landfill were observed there on occasion from 2004 - 2006 during the breeding season.

Factors Affecting Nest Site Use

Nest site use was best predicted by distance to nearest neighbor (100% importance ranking) and type of nest site (90%). The regression tree model had high predictive accuracy for both the learn data (AUC = 0.97) and the test data (AUC = 0.89). Sites were most likely to be used for nesting when the nearest nesting neighbor was roughly 7 km away (Table 3.2, Fig. 3.4). Processing facilities, bridges, ARS radar towers, and inactive rigs were more likely to be used as nest sites than drill sites and warehouses, both of which had negative partial dependence values (indicating these structures were more likely to not be used as nest sites; Fig. 3.5). All types of food subsidies ranked half as important as distance to nearest neighbor in predicting nest site use.

Breeding Biology

Interviews and informal conversations with oil field workers indicated nest building was initiated as early as February. Based on backdating of nests, ravens began laying eggs in late March until mid-May, with most nests initiated in April (Fig. 3.6). The nestling stage (hatch until fledge) lasted from mid-April through early July. Fledging occurred from early June until mid July, with most chicks leaving the nest in June; most nests in 2005 fledged later than in other years. Nests on drill sites initiated 13.5 ± 5.4 days later than those on processing facilities, and 7.1 ± 6.5 days later than on other structures (Fig. 3.7).

Overall, most raven nests (70%) were successful and more so in the eastern region (Table 3.4). Successful nests produced an average 3.9 ± 1.4 fledglings per pair (range 0 - 7). Although nest success was lower in the western region (Table 3.4), especially in 2005 (33%, n = 9), productivity between regions was similar for nests that produced fledglings. More fledglings were produced per nest attempt in 2006 (3.7 ± 1.8, n = 25) and 2004 (3.1 ± 1.9, n = 18) than 2005 (2.3 ± 2.2, n = 21). Drill site nests were less successful (55%) and produced fewer fledglings (2.0 ± 2.0, n = 22) than nests at processing facilities (77%; 3.6 ± 1.8, n = 31) and other structures (82%; 3.6 ± 1.9, n = 11).

Factors Affecting Productivity

The suite of variables I tested were not strong predictors of productivity. Initiation date and individual nest site were the only potential factors related to productivity. Individual nest site was roughly half as important (44%) as initiation date (100%) and all other variables ranked zero. The regression tree model had high predictive accuracy for *learn* data (AUC_{none} = 1.0, AUC_{low}= 0.95, AUC_{high}= 0.96), but much lower accuracy for *test* data (AUC_{none}= 0.79, AUC_{low} = 0.51, AUC_{high}= 0.59). These results indicate nest initiation date and individual nest site describe productivity of ravens nesting on the North Slope oil field, but little inference can be made beyond this population.

DISCUSSION

The breeding population of ravens in the oil fields is very productive and may be close to maximum capacity based on limitations of suitable nest sites and spacing from other raven nests. The most important factor in predicting nest site use was proximity to other ravens nests, indicating that social factors were important in nest distribution and determining which structures were used for nesting. Processing facilities, bridges, ARS towers, and inactive rigs were frequently used as nest sites while drill sites and warehouses, despite being numerous, were not; this suggests that some structures were more suitable than others. Structural differences did not explain raven productivity but my results suggest that nest initiation and individual nest site (a proxy for individual ravens) may affect their reproductive performance. Timing of nesting, and individual age and experience influence reproductive success in many avian species (Martin, 1995; Drent, 2006; Verhulst and Nilsson, 2008). Finally, proximity to food subsidies did not explain nest site use or productivity, contrary to my hypotheses. Overall, my results may be confounded by spatial and temporal correlations between the layout of structures relative to the landfill and camps, and individuals that reuse particular nest sites year after year.

Nest site use

Social Factors and Territoriality

Nest spacing, which I evaluated as distance to nearest neighbor, was the best predictor of use of nest sites in the oil field. Ravens are territorial, yet show great flexibility in their tolerance of nesting close to other ravens (Boarman and Heinrich, 1999). Nest density in the oil field (0.04 nests/km^2) falls at the low end of the range for ravens throughout their geographic range (0.01 - 0.73 nests/km^2; Dunk et al., 1994; Ratcliffe, 1997; Boarman and Heinrich, 1999; Marzluff and Neatherlin, 2006; White, 2006; Kristan and Boarman, 2007). Nests in my study area were unlikely to be closer than 4 km to each other in contrast to common (<1 km, Boarman and Heinrich, 1999) and Chihuahuan ravens (*C. cryptoleucus,* <1 km, Burton and Mueller, 2006) elsewhere. Many of the environments where nest density has been assessed for ravens have natural nest substrates; therefore the lower densities I observed suggest that nest density in the oil field may be driven in part by the layout of available and suitable structures for nesting. Nest density in the oil field was most similar to that in Iceland (0.02-0.03

nests/km^2), where ravens nest on cliffs, although Skarphedinsson et al. (1990) considered densities difficult to estimate because of the patchy distribution of suitable nesting habitat. Availability of suitable nesting habitat has been suggested as the main limiting factor for breeding ravens on islands in the Mediterranean where cliffs were in limited supply (Sara and Busalacchi, 2003). Where natural nest substrates are abundant, anthropogenic food sources influence raven nest density and territory size (Roth et al., 2004; Marzluff and Neatherlin, 2006; White, 2006; Kristan and Boarman, 2007). Though food subsidies were not important factors explaining nest site use in the oil field, nests were denser in the eastern region where there were more structures closer together, more camps, and the Prudhoe Bay Landfill.

In other areas, site use is influenced by prior nest success (Tryjanowski et al., 2004), and evidence of prior nesting activity (e.g. old nests; Steenhof et al., 1993; Kristan and Boarman, 2007). I found that ravens nesting in the oil field reused their old nest sites, including a few whose nests failed the previous year. In addition, several processing facilities were used for many years as nest sites prior to this study (Backensto and Kofinas, 2010). Informal conversations with personnel at NorthStar Island, a processing facility located 6 km offshore, indicated ravens visited the structure immediately after its establishment; this structure was used for 3 consecutive years during this study. Bridges, ARS towers, and inactive rigs, like drill sites did not have the same history of use as processing facilities, but three inactive rigs were used repeatedly over the course of this study. Ravens are long lived and perhaps many years of breeding success at a nest site outweighs the occasional failure, especially where structures for nesting are limited. Oil field workers observed that some marked breeding adults remained on or near their territories throughout the year (Powell and Backensto, 2009), similar to ravens elsewhere in the Arctic (Skarphedinsson et al., 1990). The individuals that remain, possibly to deter future prospectors, may be more experienced and older individuals who settled and retained the best territories (Fretwell and Lucas, 1970).

Human persecution may also affect raven nest distribution. In Greenland, Iceland, Britain, and Ireland where ravens are heavily persecuted, nest densities may be lower than the habitat can support, in part because survival in these areas is lower (Skarphedinsson et al., 1990; Ratcliffe, 1997; Restani et al., 2001). Ravens were not persecuted in the oil fields; however, in the village of Barrow (320 km northwest of the oil fields), a raven pair (unmarked) renests each year in the same location despite the removal of eggs and chicks from the nest annually (per conditions of Steller's Eider Recovery Plan; USFWS, 2002).

In arid environments such as the Mojave Desert, water sources, especially those associated with human developments, influenced nest distribution (Kristan and Boarman, 2007). I did not measure water availability in the oil field, because it was not limited in my study area.

Use of Structures and Structure Characteristics

I suggest that structural complexity was also an important factor in raven nest site use in the oil fields. Processing facilities, bridges, ARS towers, and inactive rigs were the most complex structures and used more frequently as nest sites than drill sites and warehouses. The range of nest height in this study was wide (3 - 30 m) and similar to the range of nest heights observed for ravens nesting on trees and cliffs elsewhere in North America (3 - 30 m, Boarman and Heinrich, 1999). Complex structures in the oil fields provide opportunities for nest placement at various heights and types of substrates. In contrast, drill sites were smaller and limited in size and number of exterior features. Milne Pt., in the western region, had the most modern drill site modules built roughly 16 years after the first drill site modules (National Research Council, 2003). Drill sites at Milne Pt. were considerably shorter than those in the eastern and other portions of the western region in Kuparuk, and I found no ravens nesting there. Warehouses in Deadhorse were not used by nesting ravens and were similar in height to drill sites and had less exterior features than all other types of structures.

Substrate suitability may also explain why complex structures were used more frequently as nest sites. Ravens in the oil field appeared to place their nests on stable substrates; structural beams on buildings and tank platforms were used more frequently than other substrates, and these features were less available at drill sites and warehouses. Raven nests on transmission towers in Idaho and Oregon were placed primarily on the most stable portions of towers (cross-arms) and on types of towers that had a high density of steel latticework (Steenhof et al., 1993). Ravens in Wyoming selected taller and larger trees for nesting (Dunk et al., 1997). Proper nesting substrates are likely to be important for nests in the oil field, simply because of the size and weight of industrial nesting materials. One oil field worker I interviewed (Backensto and Kofinas, 2010), who had been involved with removing an old nest, claimed "it [nest material] can fill up a 55 ga barrel drum, a lot of stuff, about 150 lbs." Drill sites at Milne Pt. and warehouses in Deadhorse were probably not used for nesting because their exterior features may not be large enough to support a nest.

Nest site preferences in the oil field may also be governed by structures that provide warm nest microclimates. Enhanced nest microclimate has been suggested as an explanation for raven use of human structures as nest sites in California, Idaho, and Oregon (Knight and Kawashima, 1993; Steenhof et al., 1993). In the oil field, nest microclimate may be enhanced by shelter, heated nest substrates, or a combination of the two. Drill site nests were the most exposed and may be used less because they have fewer options for a warm nest microclimate. Nests on drill sites were placed on heated substrates and faced south more often than those on other structures. The southern orientation sheltered nests from prevailing northeast winds, and combined with placement on warm substrates likely improved the microclimate. The combination of aspect and heated substrates was probably not available at most drill sites; I observed that many unused drill sites had less than two exterior features large enough to support a nest on the south facing side. Interestingly in 2005, five nests on drill sites in the western region failed to fledge young, though it was not colder on average than 2004 and 2006 during the incubation and nestling periods (National Climate Data Center et al., 2009). Overall, productivity was lower for nests on drill sites throughout this study. Processing facilities had many options to protect a nest and more heated features than drill sites (bridges, ARS towers, and inactive rigs did not produce heat); therefore, these structures likely have the most options for warm nest microclimates. Although I did not measure heat output directly, oil field workers emphasized numerous times during interviews and informal conversations that processing facilities produce considerably more heat in the processing of crude oil than drill sites (Backensto and Kofinas, 2010).

Anthropogenic Food Subsidies

Anthropogenic food subsidies were less important than I expected in predicting nest site use. Ravens place their nests near food subsidies in California and Washington (Marzluff and Neatherlin, 2006; Kristan and Boarman, 2007). Kristan and Boarman (2007) suggested that teasing out independent effects of anthropogenic variables on the distribution of raven nests can be difficult because variables associated with human developments and activities are often intercorrelated. My analyses had similar constraints because some of the most used structures were also spatially denser in the eastern region and closer to the landfill and camps. Additionally, defining appropriate metrics for anthropogenic food sources in the oil field, other than the landfill, was problematic. More sophisticated measures of food subsidies will be needed to fully evaluate the relationship between nest site use and anthropogenic food sources.

In general, little is known about effects of natural food availability on nest site selection or productivity for ravens (Boarman and Heinrich, 1999; Marzluff and

Neatherlin, 2006; Kristan and Boarman, 2007). However, food availability appears to influence nest density and territory size of ravens throughout their range. Sara and Busalacchi (2003) found one of the highest breeding raven densities (3.8 km^2 per pair) in the world on Vulcano Island in the Mediterranean, where natural food sources were abundant. High breeding densities were also observed in Wyoming (0.7 pairs per km^2), and Britain (0.1 pairs per km^2) where animal carcasses from livestock and hunting were common (Dunk et al., 1994; Ratcliffe, 1997). Currently there is little information about the diet and foraging activities of breeding ravens in the oil fields during nest initiation when the landscape is snow-covered and natural food sources may be limited. Raven activity at the Prudhoe Landfill suggests this is an important food subsidy during the winter (Backensto and Kofinas, 2010) when natural food is less available.

Some breeding ravens in the oil field may be forced to forage far from their nests early in the breeding season before the snow melts and natural food sources become more available. Ravens in California moved greater distances from their nests before incubation (Roth et al., 2004). Despite the snow-covered landscape, ravens find natural food sources during winter in the Arctic; in a more remote location of the North Slope, farther inland from the oil field, the winter diet of ravens included microtine rodents in addition to scavenged remains of caribou (*Rangifer tarandus*) carcasses (Temple, 1974). Ravens in the Canadian Arctic forage on the sea ice during winter by scavenging seal remains left by hunters and polar bears (*Ursus maritimus*) (Gilchrist and Robertson, 2000). Arctic foxes that died in the Prudhoe Bay area during winter

(2004-2007) were heavily scavenged, and ravens may have been one species to take advantage of that food source (E. Follmann, UAF, pers. comm.). Ravens in the oil fields may also rely on cached food during food limited periods; I observed ravens caching and retrieving food during the breeding season, and oil field workers observed winter caching behavior and extensive above-ground caches on facilities (Backensto and Kofinas, 2010).

Breeding Biology

Nest Initiation and Experienced Individuals

Productivity for ravens in the oil field varied little among nests and was high, similar to cliff-nesting ravens in Iceland (Skarphedinsson et al., 1990) and where they nest on human-made structures in Idaho and Oregon (Steenhof et al., 1993). Initiation date and individual nest site were possible explanations for productivity of ravens in the oil field. Experienced and older birds tend to initiate their nests earlier and are more productive than inexperienced and younger individuals (Martin, 1995; Drent, 2006; Verhulst and Nilsson, 2008). Despite the extreme cold, breeding phenology was similar to ravens elsewhere on the North Slope and in the Arctic (White and Cade, 1971; Skarphedinsson et al., 1990) as well as in more temperate regions of the U.S. (Dunk et al., 1997; Boarman and Heinrich, 1999; Kristan and Boarman, 2007). Ravens in the oil fields that fledged their young early overlapped with the period of nest initiation (early-mid June) for shorebirds (Liebezeit, 2004) and king eiders (*Somateria* *spectabilis*; Bentzen et al., 2008). Nests initiated later were generally less productive, similar to patterns observed for common and Chihuahuan ravens elsewhere (Dunk et al., 1997; Burton and Mueller, 2006; Kristan and Boarman, 2007). Ravens nesting on drill sites initiated their nests later and were less successful at fledging young and produced fewer offspring than those on other structures. It is possible that less experienced and/or younger ravens nest at drill sites; long-term monitoring of a larger, marked breeding population is necessary to examine this further.

Use of Anthropogenic Food Subsidies by Breeding Adults

Contrary to my predictions, I did not find a relationship between proximity to food subsidies and productivity. Foraging strategies for ravens in the oil fields may vary greatly among breeding pairs early in the nesting season when natural food sources are limited. Breeding pairs nesting at greater distances from the landfill may be forced to rely on cached food early in the nestling period when brooding is most important. Ravens employ a variety of caching tactics, some of which involve stealing from conspecifics as well as other species (Heinrich and Pepper, 1998; Heinrich, 1999; Bugnyar and Kotrschal, 2002; Bugnyar et al., 2007; Careau et al., 2007). Rossow (1999) found that eggs cached by a pair of breeding ravens in northwestern Alaska retained most of their nutrients for up to three months and suggested that the cache could provision them for more than a month. Food cached on structures in the oil field may be an important source of food for ravens nesting far from the landfill before natural food sources become available.

The Prudhoe Landfill did not appear to be an important food subsidy for ravens in the oil fields during the breeding season. Fewer ravens were observed at the Prudhoe Landfill throughout the summer than other times of year. It appeared that the Prudhoe Landfill was used primarily by breeding ravens that nested close by; I observed two marked individuals from different nests 5 km away occasionally using the landfill during the summer. Also, juveniles were more commonly observed at the landfill than breeding adults. These patterns of landfill use were similar to those observed for ravens in Greenland (Restani et al. 2001). Ravens in the oil field foraged at distances less than 20 km from their nests during incubation and chick rearing (Powell and Backensto, 2009), similar to ravens nesting elsewhere (Linz et al., 1992; Roth et al., 2004; Rosner and Selva, 2005; Marzluff and Neatherlin, 2006). It is likely that ravens breeding in the oil field, especially those in the western region, rely on food sources other than the Prudhoe Landfill during chick rearing.

Prey availability is higher in the oil fields after the snow melts, when shorebirds and waterfowl initiate their nests in early-mid June (Leibezeit, 2004; Bentzen et al., 2008) and the protective subnivian habitat of small mammals disappears (Kausrud et al., 2008). Eggs and chicks of tundra-nesting birds, in addition to microtines, are part of the diet of ravens breeding in the oil field (Backensto and Kofinas, 2010; Powell and Backensto, 2009). Ravens in the oil field may shift their focus from food subsidies like the Prudhoe Landfill to natural prey resources as soon as they become available, similar to breeding ravens on Vulcano Island in the Mediterranean that prey preferentially on black rats, even when anthropogenic foods are available (Sara and Busalacchi, 2003).

CONCLUSIONS

Humans subsidize breeding ravens in the Kuparuk and Prudhoe Bay oil fields primarily by providing structures for nesting. Territorial behavior, and to a certain extent qualities of structures, explained their use by ravens for nesting. Structures in the oil field provided good nesting habitat as this breeding population is very productive. Individual age and experience of ravens were potentially important factors in their use of particular structures and productivity, but unless individuals are marked and monitored this cannot be fully evaluated.

The number and density of suitable structures for nesting may be the primary factor limiting the size of this breeding population. My results indicate that ravens preferred processing facilities, bridges, ARS towers, and inactive drill rigs for nesting over drill sites and warehouses. These preferred structures had more substrate options for nest placement and opportunities to improve nest microclimate through increased cover and heat sources directly under or near the nest. These characteristics should be evaluated in greater detail to determine if some nest microclimates are significantly warmer than others and if this factor influences raven nest site selection in the oil fields.

Pairs nesting at processing facilities, bridges, ARS towers, and inactive drill rigs were productive and initiated their nests first, so efforts to slow population growth in the oil field should focus on deterring nesting at these structures. In comparison, drill sites were marginal nest sites that produced fewer offspring, but efforts to reduce nesting at these sites should also be considered.

Finally, I suggest that the use of anthropogenic food subsidies and natural food sources by breeding ravens in the oil fields warrants further investigation. My results regarding food subsidies as explanations of nest site use and productivity are inconclusive; however, the landfill does not appear to be an important source of food to the breeding population during most of the breeding season. This suggests that breeding ravens rely on other food sources in the oil fields; therefore, predation pressure exerted by ravens on tundra-nesting birds in the oil fields may be high. A thorough investigation of the diet of breeding ravens during the entire breeding season may provide new insights into their use of anthropogenic foods and their impact as nest predators in the Kuparuk and Prudhoe Bay oil fields.

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Table 3.1. Description and justification of predictor variables used in boosted regression tree models for evaluating raven nest site use and productivity in the Alaska's North Slope oil fields.

Variable	**Description**	**Justification**
Neighbor	Distance to nearest nesting raven pair. I averaged across years for nest sites that were reused.	To account for territorial behavior (Boarman and Heinrich 1999).
Anthropogenic		
Landfill	Distance to the nearest landfill, either at Prudhoe Bay or the village of Nuiqsut.	Ravens were observed using both of these landfills and they represented a large, available food source.
Camp	Distance to nearest oil field worker camp	Camps had high levels of human activity and were areas where covered food dumpsters occurred. I observed ravens at these dumpsters over the course of the study and oil field workers observed raven activity at dumpsters during the winter (Backensto and Kofinas, 2010).
February and March Drilling Rig Activity	Distance to nearest drilling rig activity in February and March. I averaged across years for nest sites that were reused.	Oil field workers observed ravens at drilling rigs in the winter and this activity represented a dynamic food subsidy, because of its temporary nature and the food dumpsters associated with camps that accompanied the drilling rig. I used activity in February and March because according to oil field workers ravens started building nests in our study area during these months.
Site Type	This categorical variable represented our classification of nest sites by type of structure: processing facilities, drill sites, and other structures. I further subdivided "other" into two categories: 1) "other" - this included drilling rigs, towers, and bridges and 2) "warehouse".	These categories resulted from field observations and discussions with oil field workers about the heat production at these sites. Processing facilities produced more heat than drill sites but both had heated substrates. Other structures did not produce heat but were more complex than warehouse structures that emitted some heat. Warehouses had few to no exterior features suitable for nesting and typically were modular buildings.

Table 3.2. Distance (m; mean ± s.d.) of common raven nests (n = 89) to neighboring nests and food subsides in Alaska's North Slope oil fields, 2004-2007. Sample sizes for camp and landfill are n = 41, because these distances did not change year to year. Sample sizes for drilling rig activity in February and March are n = 64, because I only had rig data for 2004 - 2006.

	Nest Site Type			Region		Use	
	Facility	Drill Site	Other	West	East	Used	Unused
Neighbor	6.1 ± 3.8	7.0 ± 5.0	8.3 ± 3.9	8.7 ± 4.8	5.8 ± 3.7	7.1 ± 4.2	3.7 ± 3.5
Landfill	18.1 ± 17.1	26.1 ± 15.8	28.7 ± 18.6	41.7 ± 7.5	10.4 ± 5.8	24.1 ± 17.0	21.6 ± 17.0
Camp	6.0 ± 5.3	10.9 ± 8.6	11.3 ± 11.3	14.5± 10.0	5.5 ± 4.7	9.5 ± 8.7	5.5 ± 5.6
Rig Activity Feb	4.3 ± 3.3	8.5 ± 9.2	7.3 ± 3.5	10.1 ± 8.4	3.8 ± 2.7	6.8 ± 5.6	5.6 ± 2.6
Rig Activity March	6.0 ± 5.7	12.1 ± 12.2	6.8 ± 5.0	15.7 ± 10.3	3.6 ± 2.7	8.9 ± 8.2	6.5 ± 4.6

Table 3.3. Nest characteristics of common ravens breeding in Alaska's North Slope oil fields 2004-2007. Nest height is mean ± s.d., nest cover is the mean proportion of cover ± s.d, and all others are percents within each infrastructure type.

Nest Characteristics	Processing Facility n= 21	Drill site n = 23	Other n = 11	Total Nest Sites n = 55
Height (m)	13.6 ± 6.8	7.9 ± 3.9	12.5 ± 11.2	11.0 ± 7.3
Aspect (%)				
North	19.0	4.3	9.1	10.9
South	38.1	65.2	45.5	50.9
East	23.8	8.7	0	12.7
West	4.8	13.0	9.1	9.1
Other*	14.3	8.7	36.4	16.4
Cover (%)				
Above	0.59 ± 0.38	0.26 ± 0.36	0.83 ± 0.27	0.50 ± 0.41
Side	0.44 ± 0.19	0.26 ± 0.11	0.60 ± 0.33	0.40 ± 0.24
Substrate types (%)				
Heated Substrate	33.3	43.5	0	29.8
Exhaust vent	0	21.7	0	9.1
Structural beam	38.1	8.7	100	41.8
Cable tray	19.0	13.0	0	12.7
Communication Tower	0	8.7	0	3.6
Pipe	28.6	26.1	0	21.8
Platform ladder	14.3	0	0	5.5
Tank platform/beams	0	21.7	0	9.1

*Not all nest sites had an identifiable aspect because they were sheltered from all sides by features of the structure.

Table 3.4. Apparent nest success (%) and productivity estimates (mean ± s.d.) for common ravens nesting in the western (Prudhoe Bay) and eastern (Kuparuk and Milne Pt.) regions of Alaska's North Slope oil fields, 2004-2006. Nest success is the proportion of nest attempts that fledged at least one young. Occupied nests represent all nest attempts.

			Productivity (mean ± sd)			
	Nest Success (%)	n	Occupied Nests	n	Successful Nests	n
Western	56	25	2.3 ± 2.0	25	3.6 ± 1.2	14
Eastern	80	39	3.7 ± 1.8	39	4.0 ± 1.4	31
Total	70	64	3.0 ± 2.0	64	3.9 ± 1.4	45

Figure 3.2. Images of infrastructure used by ravens for nesting (2004 - 2007) in the oil fields on Alaska's North Slope, clockwise from left: processing facility, drill site, inactive drilling rig, and ARS (U.S. Air Force Alaska Radar System) tower. Bridges are not shown. Photo credits: processing facility by ConocoPhillips, Alaska, Inc. and all others by S. Backensto.

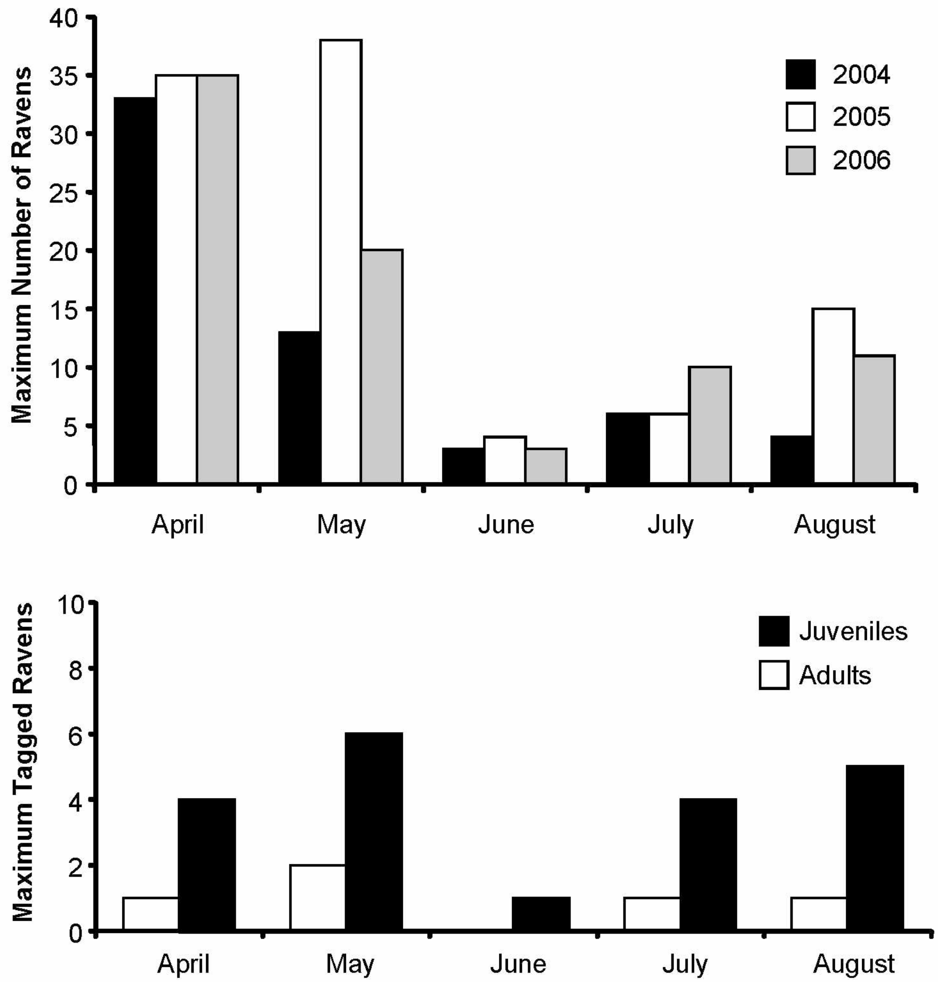


Figure 3.3. Use of the Prudhoe Bay landfill by adult and juvenile ravens during the breeding season, 2004-2006.

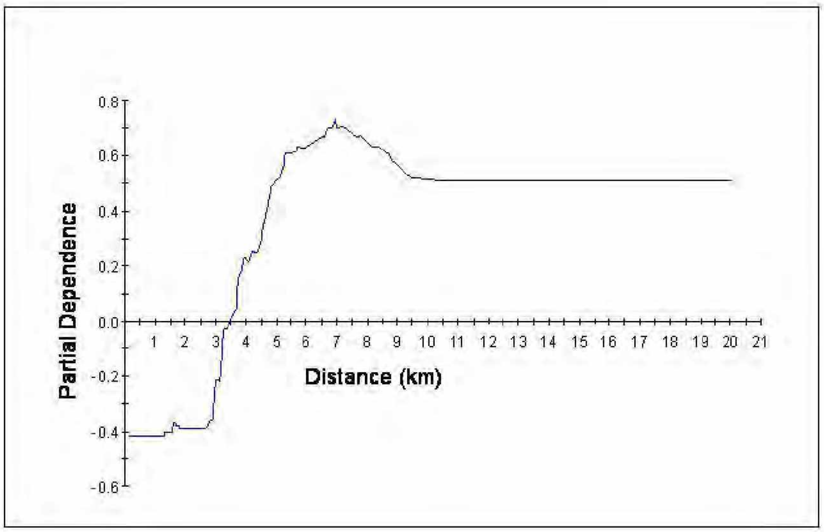


Figure 3.4. Partial dependence of nest site use on distance to nearest nesting neighbor for ravens in Alaska's North Slope oil fields. Partial dependence plots describe the strength of the relationship between the response variable and the predictor variable as trend centered on zero.

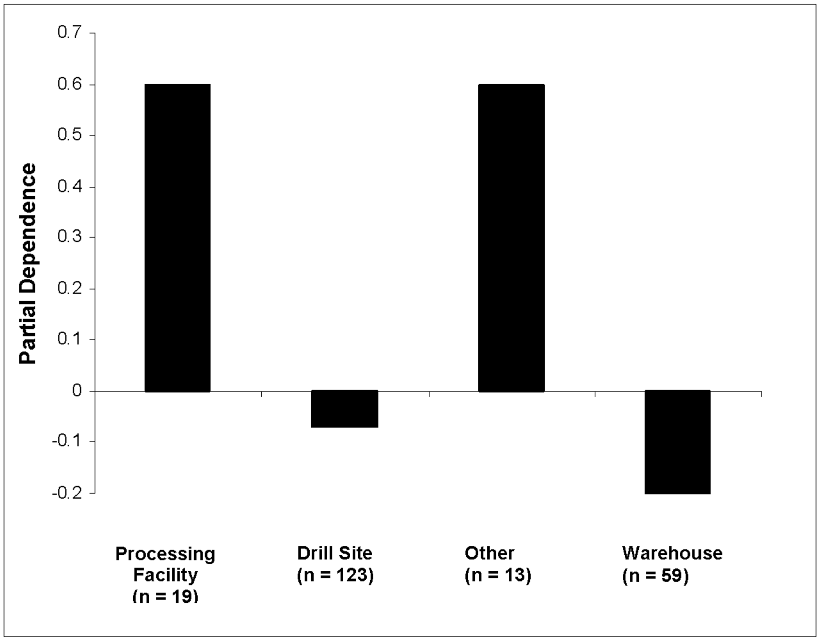


Figure 3.5. Partial dependence of nest site use on the type of structure used for nesting by ravens in Alaska's North Slope oil fields. Partial dependence plots describe the strength of the relationship between the response variable and the predictor variable as trend centered on zero. The response variable is more dependent on Processing Facility and Other than Drill Site and Warehouse.

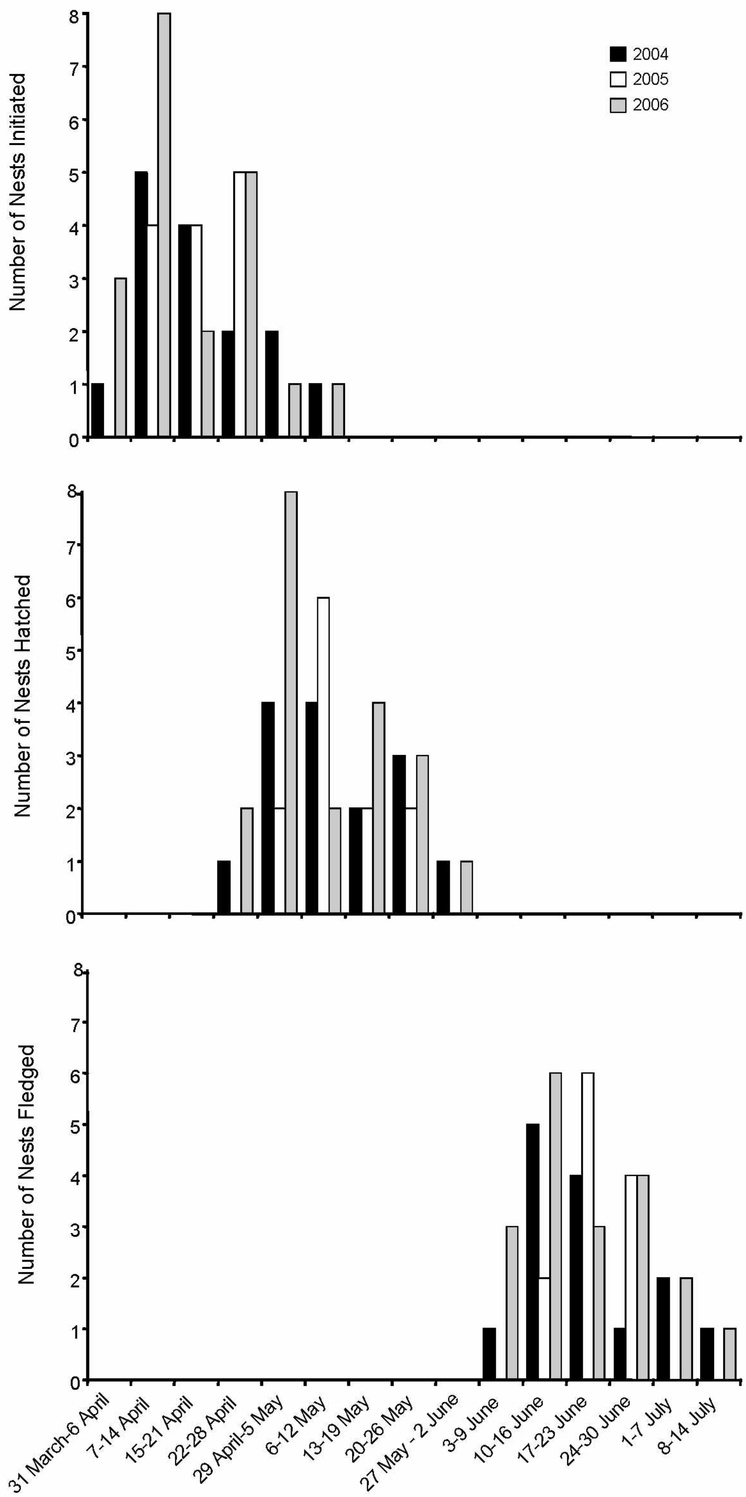


Figure 3.6. Breeding phenology for ravens nesting in Alaska's North Slope oil fields, 2004-2006.

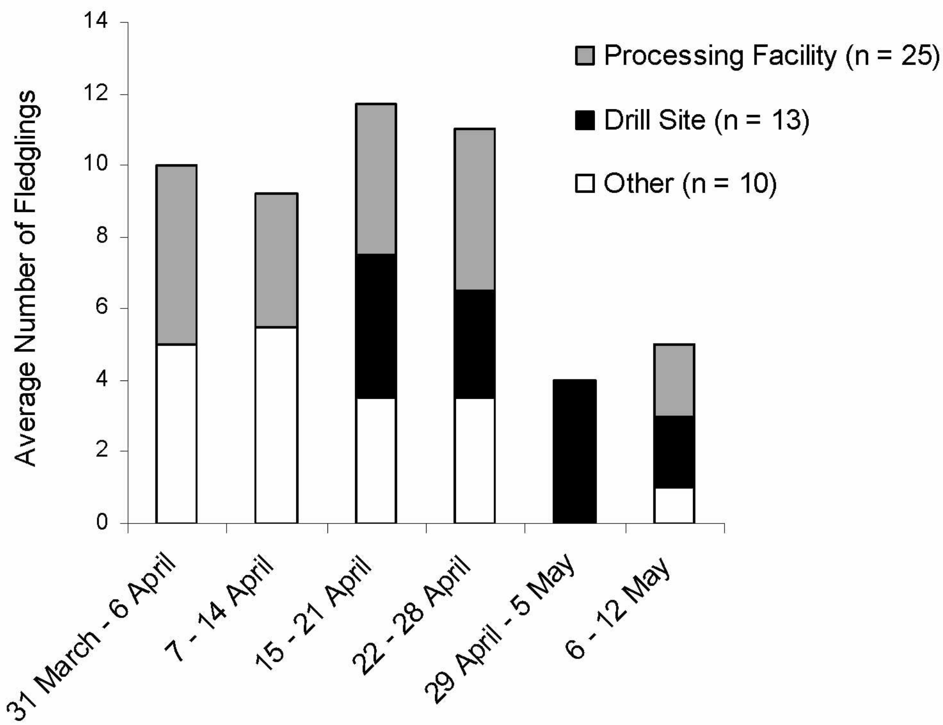
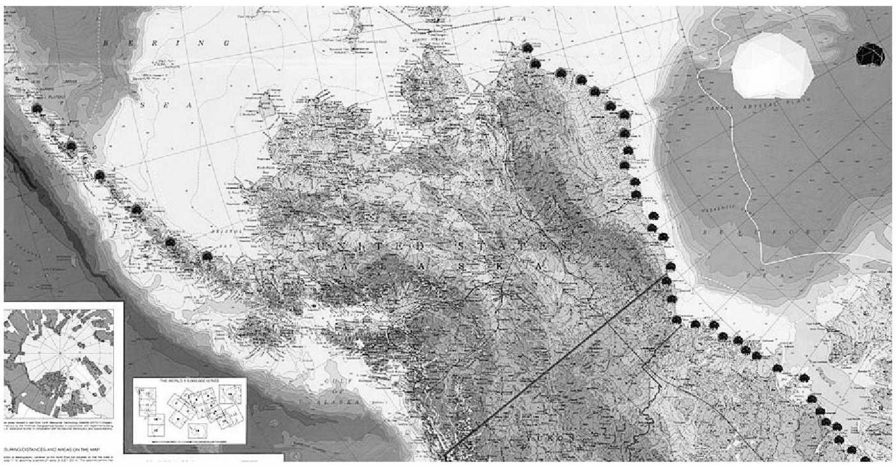
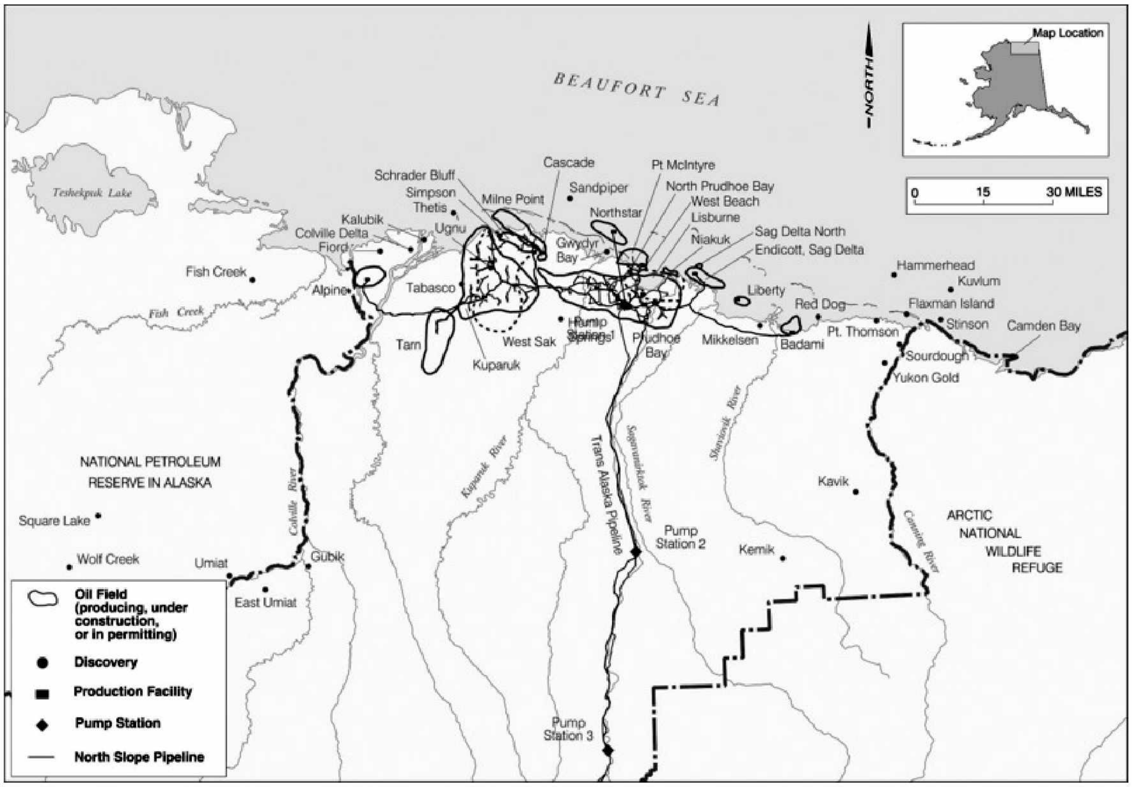


Figure 3.7. Average number of fledglings produced relative to nest initiation dates for each type of structure ravens used for nesting in Alaska's North Slope oil fields. Other includes inactive drill rigs, ARS (U.S. Air Force Alaska Radar System) towers, and bridges.

Appendix 3.1. U.S. Air Force Alaska Radar System (ARS) towers in Alaska. Dots represent locations of ARS towers, also known as the Distant Early Warning System (DEW) Line (Source: S. Fritz, Department of Anthropology, UAF).



Appendix 3.2. Location of Alaska's North Slope oil fields (Source: Trans-Alaska Pipeline System Renewal EIS, http://tapseis.anl.gov).



CHAPTER 4: DISCUSSION AND MANAGEMENT RECOMMENDATIONS

DISCUSSION

I explored raven use of anthropogenic subsidies in the oil fields using local knowledge of oil field workers and by conducting a nest ecology study. Local knowledge provided a historical perspective on raven nest site use, new information about raven activities during winter, supplemental information about the use of anthropogenic food sources, and insight into workers' values and connections to ravens. In the nest ecology study, I identified factors that may affect nest site use and productivity in this population. Taken together, these information sources indicate that structures and anthropogenic food sources in the oil fields are important to this population and that the seasonal use of some subsidies is consistent with other subsidized raven populations.

One objective of my study was to understand changes in raven abundance and use of structures for nesting over time in the oil fields. Workers' perspectives on changes in raven abundance over the course of oil field history were unclear, but some suggest that changes in policies governing management of food waste implemented during the mid to late 1990s (R. Schideler, Alaska Dept. of Fish and Game pers. comm.) may have reduced raven access to anthropogenic foods in dumpsters and pick-up trucks. Workers observed that ravens began nesting in the oil fields over 30 years ago, immediately after structures were erected. Similarly, breeding ravens in Idaho and

Oregon colonized new transmission towers the year after they were erected (Steenhof et al., 1993).

Two objectives of this study were to identify anthropogenic subsidies used by ravens in the oil fields and to evaluate nest site use and productivity of ravens relative to these subsidies. Oil field structures were used by ravens for roosting and nesting. Local knowledge of oil field workers indicated that ravens used processing facilities near the landfill in Prudhoe Bay during winter as roost sites. Use of human structures for roosting has been observed elsewhere on the North Slope and the Arctic (e.g. abandoned buildings; Temple, 1974, Watts et al., 1991), but these structures lacked heat sources, unlike processing facilities in the oil fields which likely provide warm roost sites.

I observed that structures also supplied nesting habitat for this productive breeding population of 18-25 pairs of ravens (70% successfully fledged young each year of my study). Although there were numerous structures in the oil fields, not all were suitable for nesting, and the oil field population of ravens is probably limited by the availability of suitable structures and size of breeding territories. I found that ravens nested more frequently on structures that provided opportunities for warm nest microclimates (processing facilities, bridges, ARS towers, and inactive drill rigs), suggesting that nest protection and heat sources enhanced the nest environment. Other research has suggested that human structures provide favorable nest microclimates for ravens that benefit nestlings (Knight and Kawashima, 1993; Steenhof et al., 1993). Oil field workers' insights about raven use of heat sources on structures aided in the development of hypotheses and analysis of nest site use; however, I found that most nests were not placed on heated substrates. Because I did not quantify heat near nests, I was unable to evaluate the effect of warmer nest microclimates on nest site use. However, structures that had limited options for warm nest microclimates, such as drill sites, were used less frequently and were probably marginal nest sites compared to other structures. Furthermore, individuals nesting at drill sites produced fewer offspring than ravens at other nest sites, suggesting that these structures provided inferior nest sites, or that the individuals nesting there were inexperienced. Nest site availability may also be limited by spacing requirements. Nest density was low (0.04 nests/km^2) compared to other populations (0.01 - 0.73 nests/km^2; Boarman and Heinrich, 1999), but similar to ravens in Iceland (0.02-0.03 nests/km^2; Skarphedinsson et al., 1990) where suitable nesting habitat was patchily distributed.

Anthropogenic food associated with the landfill, pick-up trucks, dumpsters, and human activity was another type of subsidy ravens used. However, contrary to other raven studies (Boarman et al., 2006; Marzluff and Neatherlin, 2006; White, 2006; Kristan and Boarman, 2007), I did not find that proximity of nests to anthropogenic food sources affected nest site use or productivity. Ravens use of the landfill in Prudhoe Bay was lower during the breeding season than during winter, which was similar to ravens in Greenland where activity at a landfill waned during the summer when other natural food sources were available (Restani et al., 2001). The daily patterns of raven activity that workers observed between the main roost site at Prudhoe Bay and the landfill during winter have previously been witnessed in other raven populations that use landfills (Heinrich, 1988; Watts et al., 1991; Restani et al., 2001; Sara and Busalacchi, 2003; Preston, 2005; Boarman et al., 2006; Janicke and Chakarov, 2007; R. King, USFWS pers. comm.; F. Huettmann, UAF pers. comm.). The shift of ravens away from the landfill in Prudhoe Bay during summer may be attributed to an increase in prey availability on the tundra and spacing of breeding pairs widely across the oil fields. I observed, as did workers, that ravens preyed on nest contents, birds, and small mammals during summer months (May-August). Regurgitated raven pellets collected near their nests in the oil fields contained mostly small mammals (55%) and avian remains (19%; Powell and Backensto, 2009). More research is needed to determine raven use of natural food sources to fully understand the relationship between prey availability and raven breeding density and success, as well as the impact ravens have on tundra-nesting bird populations.

In contrast to the landfill, seasonal use of anthropogenic food associated with pick-up trucks, dumpsters, and human activity by ravens was unclear. These food sources did not affect nest site use or productivity. Workers observed ravens removing food from the beds of pick-up trucks year-round despite oil company policies to keep food in the cabs. I took advantage of this fact to capture ravens for marking (Powell and Backensto, 2009). Workers' observations also suggest ravens may still find food at dumpster sites despite oil company policies in place since the early 1990s that require food dumpsters to be covered. Ravens may acquire food from covered dumpsters when doors are left open or food is improperly deposited. In contrast to food dumpsters, dumpsters storing industrial materials were not covered, and workers indicated they were a source of nesting materials for ravens. Although workers frequently observed ravens investigating pick-up trucks and in areas where work activity was high, increased numbers of people may not necessarily translate into improved access to anthropogenic food.

Another objective of this study was to describe how oil field workers characterized and personally related to ravens, as well as their receptiveness to the idea of reducing the raven population. In general, their feelings towards ravens were representative of the wide range of ways other cultures and societies have characterized ravens (Nelson, 1983; Heinrich, 1999; Marzluff and Angell, 2005). Although some workers were frustrated with ravens because they interfered with oil production activities, most workers admired and respected ravens. Future efforts to reduce raven numbers in the oil fields may illicit negative reactions from this community. In general, workers believed it would not be feasible to reduce nesting activity and numbers of ravens.

Currently, there are 905 oil and gas leases for more than one million hectares of the North Slope, including the foothills of the Brooks Range (Alaska Department of Natural Resources, 2009). The expansion of oil and gas activities eastward toward the Arctic National Wildlife Refuge, westward into the National Petroleum Reserve (NPR-A), and south toward the Brooks Range may provide new structures that could increase the amount of breeding habitat for ravens in these areas. However, ravens did not nest on the most modern structures (drill sites) located at Milne Pt. in Prudhoe Bay. If oil companies continue to design and construct smaller structures, like those at Milne Pt.

or the Alpine oil field (to the west) with fewer options to place a nest, ravens may have limited options for nesting in new oil fields. Oil companies should also consider that new oil and gas activities may provide ravens access to anthropogenic food.

The extent of predation pressure exerted by breeding ravens on tundra-nesting birds in the Kuparuk and Prudhoe Bay oil fields is still relatively unknown. Future research should investigate foraging activities of breeding ravens. Based on my study, I developed a set of management recommendations primarily for the breeding population and the role of local knowledge in future raven research, monitoring, and management.

MANAGEMENT RECOMMENDATIONS

The management recommendations I suggest for ravens in the oil fields stem from a need to address the growth of the raven population in the oil fields, predation impacts on tundra-nesting birds, and the careful consideration of the role of oil field workers in monitoring and managing this raven population. Limiting the breeding population's ability to reproduce is critical for reducing the impact that ravens have as nest predators in the oil fields for the following reasons: 1) raven nests are distributed widely across the oil fields, 2) the landfill was not an important anthropogenic food source during the breeding season, suggesting ravens forage on natural food items during this time, 3) ravens foraged near their nests (within 5-10 km^2 around the nest; Powell and Backensto, 2009), suggesting that tundra-nesting birds that breed near raven nests are at risk, 4) ravens fledged their young when tundra-nesting birds initiated their nests, and 5) some juvenile ravens remain in and near the oil fields after leaving their natal territories (Powell and Backensto, 2009) and thus contribute to more ravens in the area. I suggest the following measures for deterring successful reproduction by ravens in the oil fields: nest removal and manipulation, modification of structures to deter nesting, limiting access to nest materials, and continued efforts to reduce access to anthropogenic food sources. I also suggest that oil companies and wildlife managers regard oil field workers as important sources of information about this population and involve them in raven management activities.

1) *Nest removal and manipulation*

Although labor intensive, removal of nests with eggs or manipulation of eggs to prohibit hatching may be the best methods for reducing the number of nests that successfully fledge young. Nest removal was suggested as a primary method for slowing population growth of ravens in the Mojave Desert because of the low likelihood of second nest attempts and their success (reviewed in Boarman, 2003). Likewise, ravens in Poland were less likely to reuse nest sites on power pylons where nests had been destroyed previously (Tryjanowski et al., 2004). In Iceland however, most pairs that lost nests to storms early in the incubation stage rebuilt and re-laid within 2 weeks of nest failure (Skarphedinsson et al., 1990). In the Alaskan oil fields it appeared that pairs did not attempt to re-nest if they failed 1-4 weeks after initiating their nests. Ravens may be more likely to rebuild if their nest is removed prior to egg-laying, as I observed on two occasions after nests were removed by oil company personnel.

The main limitation with a nest removal strategy is that it may require efforts to remove subsequent nest building attempts, particularly if nests are removed shortly after initiation. Processing facilities should be given priority for nest removal; 45% of all nests were on these structures, most of which (77%) fledged young each year. These nests typically initiated early and should be removed in late April and early May shortly before eggs hatch. Nest removal at inactive drill rigs, bridges, and ARS towers should also be attempted during the same time period, but it may be more difficult to monitor them for subsequent nest attempts because workers generally spend little time at most of these structures. Drill sites should be focused on last because nests there were typically initiated 1-2 weeks later and were less productive nest sites (55% fledged young each year).

Nest manipulation should also be considered; eggs dipped in corn oil prevents hatching, but adults continue to incubate and thus are less likely to renest (reviewed in Boarman, 2003). This method would likely keep territorial pairs on the site, at least through the incubation period, and deter other ravens from attempting to nest in the area. In Barrow, Alaska, one pair of ravens nests near the village each year. Wildlife managers wait until the chicks hatch, then remove them from the nest. The adult pair remains and defends the territory after the removal of chicks from the nest, preventing other ravens from using the site in a given breeding season (USFWS, 2002). Nest removal or manipulation should include removing the nest at the end of the breeding season because 44% of marked ravens reused nests in subsequent years. In addition, nesting materials may cause damage to structures because of their weight, corrosive properties, and potential electrical hazards.

2) *Modification of Structures to Deter Nesting*

Modifying human structures to make nesting more difficult has been suggested for managing ravens in the Mojave Desert that impact endangered desert tortoises (Boarman, 2003), and should be considered in the oil fields to discourage breeding activities. Modification of inactive drill rigs, bridges, ARS towers, and drill sites may be more feasible than processing facilities because they are smaller and structurally more simplistic. Inactive drill rigs should be considered first; they were used consistently for nesting during my study and were productive nest sites. Bridges and ARS towers may be the easiest structures to modify because they have a limited number of support beams that could support a nest. Netting applied to support beams that are at least 3 m above the ground (no nests were found below this height) may be useful in deterring nest building (Stevens et al., 2000). Roughly half of all nests at drill sites were placed on exhaust vents and or large diameter pipes; the top portion of these features could be modified by creating steeper angles or installing tactile repellants (Belant, 1997). Pricklers (www.absolutebirdcontrol.com) should be considered because sticky substances may fail below -9° C, as well as trap smaller birds that land on these surfaces (Belant, 1997; Transport Canada (Civil Aviation), 2009).

3) *Nesting Deterrents*

Hazing ravens with audio and visual techniques like those used for birds elsewhere (Stevens et al., 2000; Gilsdorf et al., 2002) may have limited utility in the oil fields for deterring nest building; ravens were regularly disturbed at their nest sites by human activities and loud noises and habituated to these disturbances. Methods such as pyrotechnics used to disperse other species (Belant, 1997) are not feasible in this environment because of combustible gasses and flammable liquids near nest sites. Mylar at nest sites may be effective for some ravens, but birds are known to habituate to this visual stimulus (Gilsdorf et al., 2002) and, moreover, ravens are attracted to shiny objects (Heinrich, 1999).

4) *Reduced Access to Material Dumpsters*

Most nests in the oil fields were made of industrial materials and ravens appeared to find these materials in dumpsters; therefore, covering material dumpsters may limit access to some sources of nest materials and thus ravens' ability to build nests. It is likely that ravens will pilfer materials from other locations, but dumpsters represent an obvious and accessible source of these items and can be easily controlled.

5) *Continued Food Control*

Oil companies should be commended for their policies and commitment to reduce the availability of anthropogenic food to wildlife; however, more attention should be given to food and trash bags in the beds of pick-up trucks. Most oil field workers in this study (81% of questionnaire respondents) observed ravens at pick-up trucks. While this does not appear to be a consistent source of food available to ravens, pick-up trucks may yield some benefit, especially during food-limited periods. Truck windows and doors should remain closed when not in operation as some ravens were observed entering cabs in search of food.

The landfill was more important to ravens in winter than summer. Landfill employees observed more than double the number of ravens there during winter than I observed during summer. Modifying the landfill to completely exclude birds is probably not a feasible option; however, hazing ravens during the winter should be considered as a method to deter large groups from using this food source. Additionally, incinerating all food wastes at the landfill should be considered as a way to reduce access to this food source; glaucous gull (*Larus hyperboreus*) use of garbage as a food source near the landfill in Barrow, Alaska declined after incineration practices were implemented in waste handling (Weiser and Powell, *unpubl.*)

6) *Opportunities for Research and Monitoring with Oil Field Workers*

Involving oil field workers in both research and monitoring of ravens in the oil fields has great potential to improve scientific knowledge of this population. I suggest that wildlife managers and oil field companies consider implementing a raven monitoring program with oil field workers to supplement oil companies' current research and monitoring efforts. Community ecological monitoring programs elsewhere have successfully integrated scientific and local observations to monitor change in ecological systems (Kofinas et al., 2002; Vasquez-Leon et al., 2002; Curtin, 2007). Conducting research and monitoring wildlife populations in the oil fields is expensive and logistically complex, which may limit the scope of research efforts. I have demonstrated that oil field workers have a clear interest in ravens, and that many are likely to be receptive to participating in this type of effort.

For example, I explored using local workers and the general public to monitor ravens by soliciting observations of marked ravens through emails, phone calls, and a web-based program (http://www.uaf.rap/raven). From 2004-2008, 332 observations of ravens were reported by oil field workers, and 233 were reported by the general public. This effort was most successful from 2004-2006, but participation tapered off in 2007, when there was no longer a researcher associated with this project present in the oil fields. Workers' observations yielded information about adult and juvenile movements within the oil fields (Powell and Backensto, 2009) that would have otherwise been difficult to collect. This approach, while promising, is a time consuming process in terms of data management and quality control. The success of a community monitoring program will require regular communication with participants, on-going efforts to encourage participation, efforts to maintain a high research profile and increase visibility of the project, maintenance and expansion of the existing website, and improved data management techniques. Finally, no monitoring program is worthwhile unless specific objectives are developed and the data are analyzed and used.

As a result of my research, there is now a marked population of ravens in the oil fields; monitoring marked individuals may yield new insights about fidelity to nest sites and the role of individual experience in productivity. More observations of breeding individuals may also shed light on territory use and the relative importance of prey items and anthropogenic resources for the breeding population. In addition, most of the ravens marked as juveniles during my study are now of breeding age. Monitoring efforts may provide information about the age structure of the population and whether chicks produced in the oil fields eventually become part of the breeding population.

Monitoring of ravens during the winter may also provide information about their use of anthropogenic food sources and roosting activities when these resources may be critical for the population. Ultimately this information will be important for potential management activities aimed at reducing population growth by limiting over-winter survival.

An additional benefit of community monitoring may be that observations of other local ecological phenomena are collected. Ravens may be a cultural keystone species (Garibaldi and Turner, 2004) to oil field workers as they often link observations of ravens to other ecological phenomena. For example, during interviews and informal conversations with workers, I found that they often talked about other animals in relation to ravens.

7) *Involving Oil Field Workers in Raven Management Plans and Efforts*

The success of raven management activities in the oil fields will be improved if oil field workers are part of the design and implementation processes. Workers have site-specific information about how ravens use infrastructure, which may be important for identifying and evaluating options aimed at managing specific breeding pairs. Workers observed nest building behavior and are probably the best gauge of when nests are initiated; therefore, their information will be critical for timely removal of nests and responding effectively to new nest attempts. Given the variability of nest characteristics for this population, it is likely that management strategies will need to be developed on a case-by-case basis for individual pairs. Because workers tend to be familiar with specific pairs' breeding activities, they can suggest specific aspects of their facilities that should be modified to deter ravens from nesting in specific areas. Similarly, their understanding of how specific pairs of ravens respond to human activities may be important for finding appropriate and meaningful ways to change their own behaviors that affect how ravens find and access some sources of anthropogenic foods. Workers should also be consulted in management decisions because they understand how ravens impact and interfere with production activities, and how they are directly affected by the safety and health issues ravens present, such as working near aggressive ravens, electrical and corrosive hazards of nesting materials, and accumulations of feces near nests and at roost sites.

8) *Values and Cultural Significance of Ravens to Oil Field Workers*

Management of ravens in the oil fields will have a human values dimension that oil companies and wildlife managers need to address. In general, ravens are well liked by oil fields workers and have significant personal meaning; therefore, raven management in this environment may generate controversial reactions from workers. Negative reactions by the general public to lethal population control of ravens in the Mojave Desert resulted in legal actions against government agencies that halted management efforts (Boarman, 1993). I was first exposed to local sentiments about ravens while live-trapping them near facilities. I was forced to abandon capture efforts at one location because of negative reactions by some workers. Other, similar situations required that I participate in lengthy discussions with oil field workers about the merit of marking ravens. Managing breeding pairs that have a long history of nesting at some facilities in the oil fields will be challenging given that some workers have a long-standing relationship with these ravens, and they acknowledge their cultural significance. The type of actions wildlife managers suggest will likely influence workers' receptiveness to the idea of managing ravens; therefore, workers should be engaged in exploring realistic and agreeable management options.

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